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ABSTRACT

This module is the third in a series of electronics publications and serves as a supplement to "General Electronics Technician." It is designed to provide students with an overview of the broad field of communications. Included are those tasks above the basic skills level that allow students to progress to a higher level of competency in the specialized areas of communications electronics. The module contains 16 instructional units that cover the following topics: orientation; soldering and bonding techniques; amplifiers; integrated circuits; microprocessors; modulation/demodulation techniques; receivers; transmitters; introduction to video; transmission lines; antennas and propagation; two-way communications; introduction to microwave and satellite systems; optical communication devices and systems; telephone systems; and data communications. Each instructional unit follows a standard format that includes some or all of these eight basic components: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to tests and assignment sheets. All of the unit components focus on measurable and observable learning outcomes and are designed for use for more than one lesson or class period. Instructional task analyses; a glossary; a list of tools, equipment, and materials; and 27 references are also included. (KC)

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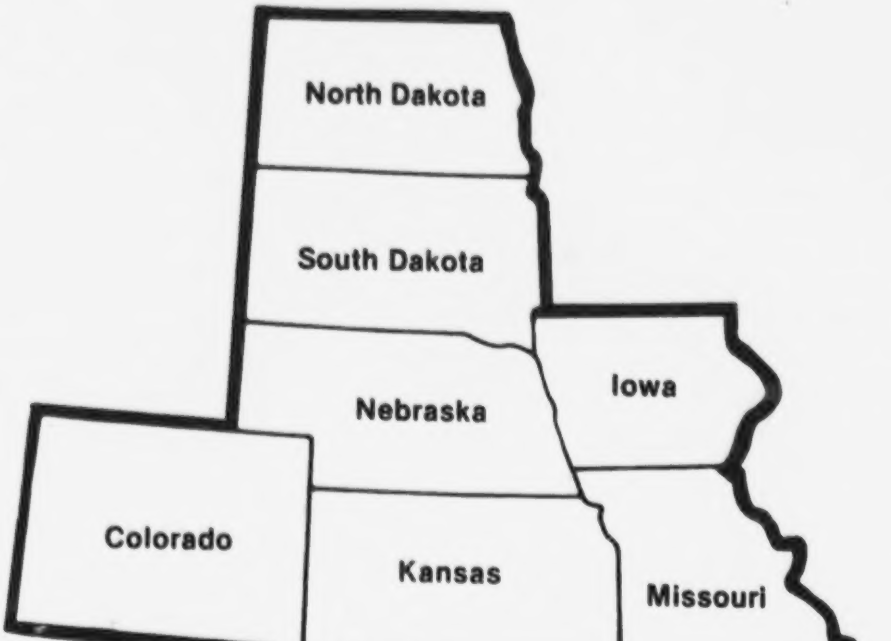
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COMMUNICATIONS ELECTRONICS

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FOREWORD

Communications Electronics is the third in a series of electronics publications and serves as a supplement to *General Electronics Technician*. This publication is designed to provide students with an overview of the broad field of communications. Included are those tasks above the basic skills level which allow students to progress to a higher level of competency in the specialized areas of communications electronics.

Every effort has been made to make this publication basic, readable, and by all means, usable. Three vital parts of instruction have been intentionally omitted from these publications: motivation, personalization, and localization. Those areas are left to the individual instructors and the instructors should capitalize on them. Only then will this publication really become a vital part of the teaching-learning process.

Ron Mehrer, Chairman
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USE OF THIS PUBLICATION

Instructional Units

Communications Electronics contains sixteen units of instruction. Each instructional unit includes some or all of the basic components of a unit of instruction; performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the tests. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

A. The amount of material that can be covered in each class period
B. The skills which must be demonstrated

    1. Supplies needed
    2. Equipment needed
    3. Amount of practice needed
    4. Amount of class time needed for demonstrations

C. Supplementary materials such as pamphlets or filmstrips that must be ordered
D. Resource people who must be contacted

Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

Suggested Activities for the Instructor

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

Information Sheets

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

Transparency Masters

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

Assignment Sheets

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which is a necessary prerequisite to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

Job Sheets

Job sheets are an important segment of each unit. The instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

Test and Evaluation

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

Test Answers

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

COMMUNICATIONS ELECTRONICS

INSTRUCTIONAL TASK ANALYSIS

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
UNIT I: ORIENTATION	
1. Terms and definitions	
2. General safety practices	
3. Events in the history of electronics	
4. Types of industries in which careers in electronic communications are available	
5. Regulating agencies for electronic communications	
6. Major activities of the FCC	
7. Bands within the frequency spectrum	
8. Radio operator licensing and certification agencies	
9. Catalogs, publications, and their uses	
	10. Explore careers in electronic communications.
UNIT II: SOLDERING AND BONDING TECHNIQUES	
1. Terms and definitions	
2. Factors affecting PC board repair	
3. Types of PC board materials	
4. Conductor weights commonly used on PC boards	

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
5. PC board construction	
6. Types of PC board circuitry	
7. Types of PC board coatings	
8. PC board coating removal methods	
9. Component mounting methods	
10. Specialized tools used in PC board fabrication and repair	
11. Soldering/desoldering procedures	
12. Types of electronic connectors	
13. Repair methods for PC boards	
	14. Determine PC board construction.
	15. Prepare a soldering iron for use.
	16. Solder electronic components to a PC board.
	17. Desolder electronic components.

UNIT III: AMPLIFIERS

1. Terms and definitions
2. Basic amplifier principles
3. Transistor amplifier configurations
4. Stabilization of transistor amplifiers
5. Types of distortion
6. Methods of coupling
7. Classes of amplifier operation
8. Fundamentals of harmonic generation

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
9. Characteristics of narrow-band amplifiers	
10. Component malfunctions	
11. Feedback considerations in RF amplifiers	
12. General characteristics of wide-band amplifiers	
13. Characteristics of nonsinusoidal waveforms	
14. Methods of improving frequency response for broad-band amplifier circuits	
	15. Identify component functions and malfunctions in an amplifier circuit.
	16. Construct and analyze an audio IC amplifier circuit.

UNIT IV: INTEGRATED CIRCUITS

1. Terms and definitions
2. Basic input parameters of the operational amplifier
3. Output parameters of the operational amplifier
4. Dynamic parameters of the operational amplifier
5. Advantages of active filters
6. Disadvantages of active filters
7. Types of active filters
8. Norton amplifier characteristics and circuits

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
9. Operational characteristics of switching regulator circuits	
10. Characteristics of phase-locked loops	
11. Timer circuit configurations	
12. Circuits used in configuration between analog and digital technologies	
	13. Construct a noninverting Norton amplifier and determine phase relationships and gain.
	14. Construct an inverting Norton amplifier and determine phase relationships and gain.

UNIT V: MICROPROCESSORS

1. Terms and definitions
2. Sections of a microcomputer
3. Sections of the CPU
4. Ways information flows in a microprocessor
5. Memory devices
6. Busses and their functions
7. Characteristics of the data bus
8. Characteristics of the address bus
9. Characteristics of the control bus
10. Clock and clock timing characteristics
11. Functions of interrupts
12. Steps in a microcomputer operating cycle

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
13. Characteristics of machine language	
14. Characteristics of assembler language	
15. Standards of communications for digital information	
	16. Write and run a machine language drive program to check a read/write memory (RAM) location.
	17. Use a digital voltmeter to test supply voltages on a microcomputer system bus.
	18. Use an oscilloscope to check a microcomputer clock system.

UNIT VI: MODULATION/DEMODULATION TECHNIQUES

1. Terms and definitions
2. Basic principles of the modulation process
3. Basic requirements of the demodulation process
4. Characteristics of amplitude modulation
5. Characteristics of single-sideband modulation
6. Types of AM modulators
7. Types of AM demodulators
8. Characteristics of frequency modulation
9. Frequency deviation in FM systems
10. Formula for determining modulation index

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
11. Types of FM modulators	
12. Types of FM demodulators	
13. Characteristics of phase modulation	
	14. Calculate percent of modulation.
	15. Calculate modulation index.
	16. Construct and analyze a diode detector.

UNIT VII: RECEIVERS

1. Terms and definitions	
2. Stages in an AM superheterodyne receiver block diagram	
3. Functional characteristics of stages in an AM receiver	
4. Stages in a single-sideband receiver block diagram	
5. Functional characteristics of stages in a single-sideband receiver	
6. Stages in an FM receiver block diagram	
7. Functional characteristics of stages in an FM receiver	
8. Characterics of double conversion receivers	
9. Characteristics o[illegible] and AFC circuits	
10. Specifications for receivers	
11. WWV and WWVH frequency standards	
	12. Identify the stages in an AM receiver and on its associated schematic.

RELATED INFORMATION: What the Worker Should Know (Cognitive)

JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

13. Identify the stages in an FM receiver and on its associated schematic.
14. Tune in and analyze time tones.
15. Tune in and analyze frequency tones.

UNIT VIII: TRANSMITTERS

1. Terms and definitions
2. Major components of an electronic communications system
3. Purpose of major transmitter stages
4. Characteristics of standard AM transmitters
5. Characteristics of double-sideband suppressed-carrier transmitters
6. Characteristics of single-sideband transmitters
7. Characteristics of FM transmitters
8. Transmitter measurements
9. Identify stages in an AM transmitter.
10. Identify stages in an FM transmitter.
11. Construct a simple AM transmitter and analyze transmitter waveforms.

UNIT IX: INTRODUCTION TO VIDEO

1. Terms and definitions
2. Applications of television systems
3. Standards of transmitted video signals
4. Elements of the television picture

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
5. Components within the composite color video signal	
6. Characteristics of color burst and synchronizing pulses	
7. Major stages in a color television receiver	
8. Stages in the RF tuner and their functions	
9. Characteristics and functions of the video IF amplifier	
10. Major stages of the sound section and their functions	
11. Characteristics and functions of the video detector and video amplifiers	
12. Characteristics and functions of the chrominance section	
13. Characteristics of the AGC and synchronization circuits	
14. Characteristics and functions of the deflection circuits	
15. Standards for stereo sound in television broadcast	
16. General safety precautions for television service or repair	
	17. View video waveforms.

UNIT X: TRANSMISSION LINES

1. Terms and definitions
2. Purpose of a transmission line
3. Types of losses in transmission lines
4. Types of transmission lines

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
5. Characteristics of transmission lines	
6. Characteristics of resonant and nonresonant lines	
7. Types of transmission line terminations	
8. Formula for determining standing wave ratio	
9. How to measure standing wave ratio on a transmission line using an SWR meter	
10. Matching impedances of a transmission line to that of a load	

UNIT XI: ANTENNAS AND PROPAGATION

1. Terms and definitions	
2. Basic functions of antennas	
3. Characteristics of electromagnetic waves	
4. Polarization of electromagnetic waves	
5. Characteristics of antenna length	
6. Characteristics of a half-wave vertical antenna	
7. Characteristics of a quarter-wave vertical antenna	
8. Characteristics of antenna arrays	
9. Characteristics of parasitic arrays	
10. Characteristics of driven arrays	
11. Types of radio waves	
12. Characteristics of tropospheric scatter	

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
	13. Calculate antenna length.
	14. Calculate the radio horizon for direct waves.

UNIT XII: TWO-WAY COMMUNICATIONS

1. Terms and definitions
2. Abbreviations related to communication systems
3. Two-way radio services
4. Types of microphones
5. Basic FM communications system
6. Characteristics of remote relay and repeater stations
7. Characteristics of pagers
8. Transmitter measurements
9. Types of receiver checks
10. Major test instruments used for checking communication systems
11. Characteristics of trunked and cellular systems
12. Considerations for interfacing to telephone lines
13. Install a two-way mobile radio.
14. Install a two-way mobile antenna.

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)

UNIT XIII: INTRODUCTION TO MICROWAVE AND SATELLITE SYSTEMS

1. Terms and definitions
2. Abbreviations related to microwave and satellite systems
3. Major microwave systems in electronic communications
4. Major types of microwave transmission lines
5. Devices used for coupling to waveguides
6. Major microwave solid state devices
7. Major microwave vacuum tubes
8. Major types of microwave antennas
9. Types of microwave systems
10. Microwave system gain and loss as a mathematical formula
11. Basic microwave test instruments
12. Characteristics of basic satellite communication systems
13. Identify local microwave users.
14. Identify satellite locations and programming.

UNIT XIV: OPTICAL COMMUNICATIONS DEVICES AND SYSTEMS

1. Terms and definitions
2. Abbreviations related to optical communications devices and systems
3. Stages of a TX/RX optical communication system

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
4. Types of optical communications	
5. Advantages of optical communications	
6. Parts of a fiber-optic cable	
7. Characteristics of light transmission through optical fibers	
8. Types of optical cables and their performance	
9. Characteristics of optical fiber	
10. Loss factors of optical cables	
11. Types of connectors used with fiber-optic cable	
12. Requirements of optical connectors	
13. Types of splices	
14. Basic coupler operation	
15. Couplers used in fiber optics	
16. Areas of optical cable installation	
	17. Use the multimeter to check optical diodes.
	18. Construct and analyze a detector circuit.

UNIT XV: TELEPHONE SYSTEMS

1. Terms and definitions
2. Abbreviations related to telephone systems
3. Types of communication facilities
4. Telephone centers

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
5. Communication paths used in telephone systems	
6. Local loop functions of telephone systems	
7. Types of branch exchanges	
8. Functions of a PBX key system	
9. Telephone dialing methods	
10. Ringer equivalence requirements	
11. Telephone system characteristics	
12. Private line services	
13. Subscriber line color codes	
14. Telephone number codes	
15. Local loop characteristics	
16. Transmission parameters	
17. Types of line conditioning	
	18. Analyze noise on a telephone system.
	19. Measure the ring signal of a system.

UNIT XVI: DATA COMMUNICATIONS

1. Terms and definitions
2. Abbreviations related to data communications
3. Common data codes
4. Error detection methods
5. Types of data carriers
6. Common interfaces

RELATED INFORMATION: What the Worker Should Know (Cognitive)	JOB TRAINING: What the Worker Should Be Able to Do (Psychomotor)
7. Basic types of networking	
8. Types of protocols	
9. Modems	
10. Methodologies of moving information	
11. Methods of testing data communications equipment	
12. Types of data communications test equipment	
	13. Determine parity bits for parity codes.
	14. Analyze and test a parity circuit.
	15. Construct a standard null-modem cable.

COMMUNICATIONS ELECTRONICS

GLOSSARY

A

Active filter — Filter that contains an active component such as an operational amplifier that introduces some signal gain

Address word — A binary word that the microprocessor uses as an address to determine the location of a memory or I/O word

AFC (automatic frequency control) — An electronic circuit that assures a constant IF center frequency in an FM receiver by keeping the local oscillator frequency separated from the RF amplifier signal by a fixed amount

AM (amplitude modulation) — The process by which an electronic signal is used to vary the amplitude of an RF carrier

AM receiver — An apparatus of electronic circuits designed to receive and process amplitude modulated signals

Antenna — A device used to radiate energy into space or receive energy from space

Antenna array — Antenna elements grouped to accomplish a specified gain and/or directivity

Asynchronous — The condition in which the timing of a bit or binary word does not coincide with the signal source used in the system

Attenuation — A loss of signal amplitude during transmission

Attenuator — A device that absorbs energy, thus reducing the power level

Aural — Sound or audio

AVC/AGC (automatic volume/gain control) — An electronic circuit that automatically increases or decreases the gain of a receiver in an inverse relationship with the strength of the received signal

B

Balanced line — A transmission line in which both wires of the line carry RF current, and the current in each wire is 180 degrees out of phase with the other wire

Balun — Device used for matching transmission lines to antennas

Baseband — The composite signal that contains the intelligence and control signals used to modulate the carrier in a microwave or satellite communications system

Baud rate — The total number of transmissions per second; if various size bits are transmitted, the duration of the smallest bit must be used

Beamsplitter — A light splitting device using a plate coated with a partially reflective material where a portion of the light transmits through the plate and a portion is reflected

Bit — The smallest element of information or one binary digit, either a one or a zero

Bit rate — The total number of information bits transmitted per second

Branch exchange — A switchboard located between the cable termination box and the central office to route the incoming calls

Breakout box — A text instrument placed between the DTE and the DCE to check or insert signals in the data path

Buffer — An amplifier circuit used between two stages to reduce the loading effects of one stage on the other

Byte — A string of binary digits, usually eight; operated on as a basic unit by a digital computer

C

Cable pair - The line between the cable termination box and the user which consists of two conductors

Carrier — A continuous wave radio frequency to which intelligence may be added by the process of modulation

Ceramic — White or light tan flexible board designed for use with very high temperatures

Characteristics — Inherent and measurable properties that will vary the ability of something

Characters — A specific number of ones and zeros

Chrominance signal — The color information within the composite video signal

Cladding — The layer that surrounds the fiber core and contains a low index of refraction

Clock pulse — A pulse used to synchronize a digital circuit

Co-channel interference — Interfering signal of the same frequency as the desired signal

Codec — One circuit used both as an encoder and a decoder

Color burst — A waveform of short duration that contains phase and frequency reference information for color television circuits

Combiner — A device that allows the simultaneous transmission of two signals in the same channel without interaction

Common-carrier — A station open to public correspondence; organization providing general service to the public for a fee

Common-mode signals — Voltages of equal amplitude and frequency, in-phase, and applied to both inputs of a differential amplifier

Composite video — A whole that is a combination of two or more parts, i.e. a complete video signal consisting of luminance, chrominance, sync, blanking, and color burst

Connector — A device used to connect or disconnect optical devices such as the source, detector, or fibers

Converter — A stage in a receiver that is a combination local oscillator and mixer

Coupler — A device that divides or combines light signals as required

Critical angle — Where the refracted signal is 90° from the normal

D

Data — Information which can be produced or processed by a computer which is transferred from one point to another

Data communications — The technology of transferring data from one point to another between various distances

Data word — A binary word that the microprocessor manipulates internally by moving, storing, or performing an operation on to accomplish a desired result

Decoupling — Preventing transfer or feedback of energy from one circuit to another

Decrementing — Decreasing the contents of an address or register by one

De-emphasis — Process used in the audio section of an FM receiver to attenuate high frequencies

De-emphasis circuit — A circuit used in the audio section of an FM receiver to attenuate high frequencies

Degeneration — The process of returning part of the output of an amplifier back to the input in such a way that it tends to cancel or reduce the input

Demarche — A connection device at the user facility where the local loop ends and the user equipment begins

Demodulation — The process of removing the modulation signal from the associated carrier waveform

Detector — The stage in a receiver that separates the intelligence signal from the IF frequency

Differential amplifier — An amplifier that has two inputs and amplifies the difference between inputs to produce an output

Diplexer — Coupling unit that provides for more than one transmitter to broadcast from the same antenna

Dipole — A center-fed antenna commonly used for frequencies below thirty megahertz

Discriminator — The electronic circuit in an FM receiver that separates the intelligence signal from the IF

Dispersion — A phenomena that causes broadening or spreading of light as it propagates through an optical fiber

Double conversion — Two stage process of producing first one intermediate frequency followed by the production of a second intermediate frequency

Double-sideband transmission — Method of electronic communication in which the sideband frequencies produced by the process of modulation and the carrier frequency are all transmitted

DSBSC (double-sideband suppressed-carrier) transmission — Method of electronic communication in which the sideband frequencies produced by the process of modulation are transmitted with the carrier being suppressed before transmission

Dummy load — A device that simulates all the electrical characteristics of an antenna except that the energy supplied to it is not radiated

E

Epoxy glass — Laminated epoxy and glass fiber producing a very rigid board

Eyelet — A tubular metal device used on PC boards for through connections

F

Feedback — The process used to obtain degeneration or regeneration

Fiber optics — A method of carrying information from one point to another using a thin strand of glass or plastic which carries light instead of electricity

Fiberscope — A glass rod utilized in medicine to look inside the body

Flux — A chemical that cleans metals before or during soldering and chemically acts to aid the fusion process

FM (frequency modulation) — The process by which an electronic signal is used to vary the frequency of a higher frequency carrier

FM receiver — An apparatus of electronic circuits designed to receive and process frequency modulated signals

FM transmission — Method of electronic communication in which a constant amplitude carrier wave is transmitted that varies in frequency in direct proportion to the amplitude and frequency of a modulating waveform

Full-wave dipole — A dipole antenna that has a length equal to one wavelength of the operating frequency

G

Gain — The amount by which a signal is increased or amplified

Gigahertz (GHz) — 1,000,000,000 hertz (one billion hertz)

Graded-index fiber — Fiber that consists of various layers of fiber, similar to the rings of a tree trunk

Ground plane — A common ground point for PC board circuitry

Ground start — An off-hook condition which causes a ground to be applied to half of the line relay, then when the dial tone is detected by the PBX equipment the ground start contact is opened

H

Half-wave dipole — A dipole antenna that has a length equal to half the wavelength of the operating frequency

Handshaking — An exchange of predetermined signals when a connection is made between two data-set devices

Heterodyne — To combine or superimpose frequencies to obtain a different frequency

High level modulation — Modulation produced at a point in a system where the power level approximates that at the output of the system such as collector modulation of the final RF amp

I

IF (intermediate frequency) — The frequency that results from mixing an RF signal from the RF amplifier with the local oscillator RF frequency

Image frequency — An unwanted signal that arises from a source other than that to which the receive is tuned, usually during heterodyning action in the mixer whose frequency falls within the bandpass of the IF amplifier

Image rejection ratio — The ratio of the desired signal amplitude to the image signal amplitude

Incrementing — Increasing the contents of an address or register by one

Index of refraction — A ratio of the velocity of light in free space to the velocity of light of a specific material

Induction field — A field that is associated with that portion of the electromagnetic wave that immediately surrounds the antenna

Integrated circuit — A complete circuit consisting of a number of separate component parts manufactured as a single microchip package

Intelligence signal — Electronic signal that conveys information such as voice, music, or data

Interface — The point where two components connect within a system and/or the device used to make the connection

Inverting amplifier — An amplifier that has an output signal 180 degrees out of phase with the input signal

J

Jacket — The outer sheath that insulates and protects cabling against the environment

K

Key system — A part of the PBX system which provides for centralized control of telephone functions such as intercom and paging

Kilohertz (kHz) — 1000 hertz (one thousand hertz)

Klystron — Microwave oscillator or amplifier using cavities to modulate an electron stream

L

Laminate — Material pressed into thin sheets constructed in layers

Limiter — Designed to insure constant amplitude

Local oscillator — The stage in a receiver which produces an unmodulated variable RF frequency

Loop start — An off-hook condition applying current to the line which in turn activates a relay closing the relay contacts signaling the switching circuits

Low level modulation — Method of mixing the audio and RF at a point in the transmitter prior to the plate/collector of the last stage RF amplifier

Luminance signal — The brightness information within a composite video signal

M

Magnetron — A microwave oscillator that uses the interaction of magnetic and electric fields in a complex cavity

Marconi antenna — A one-fourth-wavelength antenna that uses reflected ground to provide the missing one-fourth-wavelength

Matching stub — Device placed on a transmission line which varies the impedance of the line to provide for line-to-load impedance match

Megahertz (MHz) — 1,000,000 hertz (one million hertz)

Microcomputer — A computer system whose processing unit is a microprocessor that contains memory and input-output facilities

Microprocessor — The arithmetic logic unit, registers, and timing and decoding circuitry usually contained in a single integrated circuit that control computer activity

Mixer — The stage in a receiver which heterodynes the RF signal from the receiving antenna and the RF frequency generated by the local oscillator

Modal dispersion — Dispersion resulting from different transit lengths of various propagating modes causing the various signals to exit at different times

Mode — The path that light will follow when transmitted through an optical fiber

Mnemonics — Acronyms chosen to aid the programmer or technician

Modulation - The process by which the alteration or modification of the characteristics of one waveform or signal is accomplished in accordance with the characteristics of another waveform called a modulation signal

Multiplier — Circuit used to increase frequency to a multiple of the input frequency

Mylar flex — A very thin flexible material which may be damaged by too much pressure applied by a soldering iron

N

Network — The configuration of communication facilities that connects the user equipment to the TX/RX equipment

Neutralization — The process of nullifying the reactive feedback to prevent unwanted oscillations in an amplifier

Noise — Undesirable interference in an electronic signal

Normal line — An imaginary line perpendicular to the connecting line between the core material and the cladding material

Norton amplifier — A current driven operational amplifier circuit that amplifies AC signal

O

Off-hook — The process of lifting the handset off the telephone, completing a DC path alerting the central office of an off-hook condition (loop start condition)

On-hook — The process of returning the handset to the telephone, opening the switch hook

Operational amplifier (op amp) — An amplifier that exhibits a very high gain, high-input, and low-output impedance, has a good rejection of common-mode signals, and has differential inputs

P

Pad — Round terminal connection point on a printed circuit board where component lead wires are attached

Peripheral — Any device such as a disk drive, printer, modem, or video display added to a microcomputer to provide increased capacity for handling, storing, or presenting data

Phase-locked-loop — A closed-loop electronic circuit that contains a phase detector, low-pass filter, DC amplifier, and a voltage-controlled oscillator in a feedback loop

Phenolic resin — A construction of laminated sections of cotton or paper impregnated with a phenolic resin and used with moderate temperatures

Picture element — A single light or dark element within a picture

Potting — A process of assembling components in some type of container and filling with some type of insulating material

Pre-emphasis — Process used to enhance or amplify high frequencies in an FM transmitter

Pre-emphasis circuit — A circuit used in an FM transmitter to amplify the high frequencies

Protector — An overvoltage protection device for voltage and lightning surges of up to 1000 volts

Protocol — A communications exchange accomplished with software

R

Radiation field — That part of the electromagnetic wave that travels through space

Receiver — An apparatus of electronic circuits that receives a signal and processes the signal into a recognizable form such as voice or data

Reflected wave — A wave that is returned along a transmission line from a load back towards the source when an impedance mismatch exists between line and load

Reflector — An element in a multielement antenna that reflects a signal to the driven element of the antenna

Refraction — In optical fiber this is the deflection of light

Regeneration — The process of returning part of the output of an amplifier back to the input in such a way that it tends to aid the input

Repair — To return an item to its original condition

Repeater station — Point in a microwave system where RF carriers are amplified and retransmitted

Resolution — The fineness or detail within an image

Run — A strip of conductor material adhered to a printed circuit board used for current flow

S

Selectivity — The ability of a receiver to accept a signal and reject adjacent signals

Sensitivity — Defines the weakest signal that can be received

Sequential — The same information continues until changed, i.e. upper case and lower case characters

Sideband — Frequencies on either side of carrier signal that are produced through modulation

Sideband frequencies — Frequencies above or below the carrier frequency as a result of modulation

Signal — The varying electrical voltage or current that carries desirable intelligence

Single conversion — The process of producing a single intermediate frequency (IF) in a superheterodyne receiver

Skin effect — Tendency of currents at high frequencies to flow near the surface of a conductor

Solder — A soft metal alloy of tin (Sn) and lead (Pb) used for plating and fusing metals together

Solder joint — A junction of two or more metals, fused with solder

Speed of light — The velocity of electromagnetic energy in a vacuum (186,000 mi/sec)

Splice — A device used to make permanent connections between different fibers

Squelch circuit — Circuit for preventing a radio receiver from producing audio frequency output in the absence of the predetermined signal

SSB (Single-sideband suppressed-carrier) transmission — Method of electronic communication in which one of the sideband frequencies produced by the process of modulation is transmitted with the other sideband and carrier suppressed before transmission

Standing wave — Distribution of current and voltage amplitudes along a transmission line as a result of the deflection of energy from a point where a mismatch of impedance occurs

Standing wave ratio — Ratio of current or voltage at a maximum value point on a transmission line to a minimum value voltage or current point on the line

Subscriber — The operator or user of the transmit/receive instrument

Summing amplifier — An amplifier circuit with an output that is the sum of individual voltages applied through a resistive network to the (_) input of an op amp

Synchronous — The timing of a bit or binary word so that it coincides with a precisely timed signal source

T

Telecommunications — The practice of the transfer of information by an electromagnetic means

Telegraphy — Communication by means of a telecommunications system that transmit documentary matter, such as images or printed matter, and reproduces it at a distant location

Telemetry — Communication by a telecommunications system that is designed to transmit sound

Tensile strength — The ability of a fiber to be stretched or pulled without breaking

Terahertz (THz) — 1,000,000,000,000 hertz (one trillion hertz)

Terminal station — Point in a microwave system where baseband signals are either originated or terminated

Through connector — A copper coating lining the hole on a PC board for electrical connection

Tip and ring — Refers to the tip and ring of the telephone plug

Transmission line — Material structure forming a continuous path from one place to another and used for directing the transmission of electromagnetic energy along this path;a conductor or series of conductors used to carry energy from a source to a load

Transmitter — A device, circuit, or apparatus used in telecommunications system to originate an electrical signal that is to be transferred to another location

Tropospheric scatter — A little understood phenomena that refers to the scattering of a high power radio wave by irregularities in the earth's atmosphere

U

Unbalanced line — A transmission line in which one wire is at ground potential, while the other wire carries the RF current

V

Vestigial sideband — Small amount (vestige) that remains of a complete original sideband

Video — Picture portion of a television signal; signal that carries visual information

Voltage plane — A common voltage point for PC board circuitry

W

Waveguide — A transmission line that consists of a suitably shaped hollow conductor and is used to guide ultrahigh and superhigh frequency electromagnetic waves propagated along its length

Wavelength — The distance between two successive peaks of a signal

Wicking — The ability of solder to travel up the conductors of a wire or braid by capillary action during the process of heating

Wrist strap — A grounding strap connected to the technician's wrist and to a ground such as earth to divert static electricity from the electronic components

Y

Yagi antenna — A sharply directional antenna array commonly used for television reception

COMMUNICATIONS ELECTRONICS

TOOLS, EQUIPMENT, AND MATERIALS LIST

AM receiver
Audio amplifier, 2-watt
Audio signal generator

Cable connector plugs
Capacitors
Ceramic capacitor
Circuit wire
Clock or stop watch
C-message filter
Color bar generator
Connecting cable

dB or milliamp meter
DC power supply
DC voltmeter
Diagonal pliers
Digital voltmeter
Diode (IN4149)

Electrolytic capacitors
Electronic components
Extender card for system bus

File
FM receiver
Frequency counter
Function generator

Heat sink

IC, XOR
Inductor
Isolation transformer

LED's
Long nose pliers

Microcomputer
Mounting bracket
Mounting hardware and cable for antenna
Multimeter

Notch filter
NPN transistors

Operation manuals for equipment
Oscilloscope
Oscilloscope, dual trace

Photodiode
Portable electric drill
Potentiometer
Printed circuit boards with components
Proto board

Resin core solder
Resistors

Safety glasses/goggles
Schematic diagram of receiver
Signal generator
Sine wave
Solder
Soldering iron
Soldering iron holder
Solder remover
Speaker, 8-ohm
Sponge
Standard service tool kit
Static protection equipment
Switches
SWR meter

Television receiver
Test leads
Transistor, 2N2222
TV receiver component layout diagram
TV receiver schematic
Two-way radio unit
Two-way radio antenna

COMMUNICATIONS ELECTRONICS

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ORIENTATION
UNIT I

UNIT OBJECTIVE

After completion of this unit, the student should be able to list major activities of the Federal Communications Commission and use technical publications and catalogs available in the electronic communications field. Competencies will be demonstrated by completing the assignment sheet and the unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to electronic communication with their correct definitions.
2. Complete statements concerning general safety practices for accident prevention.
3. Complete statements concerning events in the history of electronics.
4. Name types of industries in which careers in electronic communications are available.
5. Complete statements concerning regulating agencies for electronic communications.
6. Select from a list major activities of the Federal Communications Commission.
7. Complete statements concerning the bands within the frequency spectrum.
8. Select from a list radio operator licensing and certification agencies.
9. Complete statements concerning catalogs, publications, and their uses.
10. Explore careers in electronic communications. (Assignment Sheet #1)

ORIENTATION
UNIT I

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Provide students with objective sheet.

C. Discuss unit and specific objectives.

D. Provide students with information and assignment sheets.

E. Discuss information and assignment sheets.

F. Integrate the following activities throughout the teaching of this unit:

   1. Orient the students to lab safety procedures.
   2. Identify evacuation routes and storm shelters.
   3. Point out the locations of fire extinguishers.
   4. Demonstrate how to use a fire extinguisher.
   5. Identify locations of electrical switches to be shut off in the event of an emergency.
   6. Review laws, regulations, and procedures concerning safety and the administering of first aid and CPR.
   7. Demonstrate proper use of equipment and supply catalogs.
   8. Discuss local radio frequencies used by broadcast radio and television stations.
   9. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

G. Administer test.

H. Evaluate test.

I. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Hardy, James K. *Electronic Communications Technology.* Englewood Cliffs, NJ: Reston Publishing, Prentice-Hall, 1986.

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ORIENTATION
UNIT I

INFORMATION SHEET

I. **Terms and definitions**

A. Common-carrier — A station open to public correspondence; organization providing general service to the public for a fee

B. Gigahertz (GHz) — 1,000,000,000 hertz (one billion hertz)

C. Kilohertz (kHz) — 1000 hertz (one thousand hertz)

D. Megahertz (MHz) — 1,000,000 hertz (one million hertz)

E. Telecommunications — The practice of the transfer of information by any electromagnetic means, such as wire, radio waves, or light waves

F. Telegraphy — Communication by means of a telecommunications system that transmits documentary matter, such as images or printed matter, and reproduces it at a distant location

Examples: Morse Code, weather map, facsimile

G. Telephony — Communication by a telecommunications system that is designed to transmit sound

Example: Speech

H. Terahertz (THz) — 1,000,000,000,000 hertz (one trillion hertz)

I. Wavelength — The distance between two successive peaks of a signal

II. **General safety practices for accident prevention**

(NOTE: Accidents cause lost job time, painful injuries, and needless deaths. They may be prevented by learning and practicing safe working habits.)

A. Be knowledgeable in safety and first aid procedures.

(NOTE: **DO NOT** perform CPR unless you have been certified to do so through training programs.)

B. Know the location of the nearest fire extinguisher and how to use it.

C. Know the location of the nearest telephone where emergency numbers can quickly be found.

INFORMATION SHEET

D. Know the location of the first aid kit.

E. Wear safety glasses in all work areas.

F. Know the emergency evacuation route to use for a fire emergency.

G. Know the emergency evacuation routine for a tornado alert and the location of the nearest storm shelter.

H. Use all tools and equipment for their intended purposes only.

I. Before entering the work area, remove rings, necklaces, and any metallic jewelry that might inadvertently come in contact with energized areas.

J. Do not wear loose clothing around turning machines.

K. Know all special safety procedures for your work area and adhere to them.

L. Synthetic clothing should not be worn where static electricity may be a problem.

M. Report all accidents to your instructor immediately.

III. **Events in the history of electronics**

A. In 1835, Samuel Morse used a telegraph system to send dots and dashes to communicate from one location to another.

B. In 1858, a transatlantic telegraph cable was completed.

C. In 1875, Alexander Graham Bell demonstrated the telephone.

D. In 1887, Heinrich Hertz demonstrated the transmission and reception of radio waves.

E. In 1901, Marconi successfully used a wireless telegraph to transmit Morse code across the Atlantic ocean.

F. In 1907, Lee DeForest developed the triode vacuum tube.

G. In 1947, Bell Laboratories developed the transistor.

H. In 1956, the first transatlantic telephone cable service was completed.

I. In 1959, the Fairchild company developed the planar-integrated circuit.

J. In 1970, Intel Corporation developed the microprocessor integrated circuit.

INFORMATION SHEET

IV. Careers in electronic communications

A. Careers for electronic communications technicians are available in a variety of industries.

1. Telephone
2. Satellite communications
3. Two-way radio (land mobile)
4. Broadcast communications
5. Manufacturing
6. Military services
7. Test equipment
8. Aerospace industries
9. Aviation industry
10. Television
11. Maritime radio
12. Consumer electronics
13. Computer telecommunications

B. Careers in electronic communications may involve a number of different types of jobs.

1. Sales and service
2. Equipment installation
3. Equipment repair
4. Research and development
5. Equipment and component manufacturing
6. Equipment operators
7. Test equipment calibration

INFORMATION SHEET

V. **Regulating agencies for electronic communications**

A. The International Telecommunications Union (ITU) holds the World Administrative Radio Conference every twenty years to formulate agreement on frequency uses.

1. Current agreement applies until the year 2000.

2. The world is divided into three major regions for frequency allocation purposes.

3. Allocated frequencies are administered by agencies within these regions such as the Federal Communications Commission (FCC) in the USA, the British Post Office (BPO) in the the United Kingdom, and the Federal Department of Communications (DOC) in Canada.

B. The International Telecommunications Union (ITU) has two associated international committees.

1. International Telegraph and Telephone Consultative Committee (CCITT)

2. International Radio Consultative Committee (CCIR)

C. Various bodies and committees, on behalf of the USA Standards Institute (USASI), determine the standards in the United States.

1. Electronics Industries Association (EIA)

2. Institute of Electrical and Electronics Engineers, Inc. (IEEE)

3. Joint Electronic Device Engineering Council (JEDEC)

4. National Bureau of Standards (NBS)

5. National Aeronautical and Space Administration (NASA)

6. Federal Communications Commission (FCC)

7. National Television System Committee (NTSC)

D. The Federal Communications Commission (FCC) is the major regulating agency in the USA for radio communications between the 50 states, territories, and possessions of the United States and between this country and other countries. Exceptions are facilities operated by the military and other federal government facilities.

INFORMATION SHEET

VI. Major activities of the FCC

A. Allocates bands of frequencies to various radio services

B. Assigns specific frequencies and power to individual stations

C. Regulates various radio services

D. Issues a license to television and radio stations

E. Issues a license to station operators

F. Regulates common carrier communication companies engaged in interstate communications

G. Inspects radio stations

H. Maintains a set of rules and regulations for communication by wire, cable and radio

INFORMATION SHEET

VII. Bands within the frequency spectrum

A. The frequency spectrum is divided into numerous bands with separate ranges of frequencies for each designated band.

(NOTE: Frequency ranges and their respective band designations may vary by industry.)

Frequency Band Designation	Frequency Range
Subaudible	0.001 to 15 Hz
Audio (AF)	15 Hz to 20 kHz
Power	10 Hz to 1kHz
Video	0 to over 4.5 MHz
Supersonic/ultrasonic	20 kHz to over 2MHz
Extremely low (ELF)	30 to 300 Hz
Superlow (SLF)	0.3 to 3kHz
Very low (VLF)	3 to 3 MHz
Low (LF)	30 to 300 kHz
Medium (MF)	300 kHz to 3MHz
High (HF)	3 to 30 MHz
Very high (VHF)	30 to 300 MHz
Ultra high (UHF)	300 MHz to 3 GHz
Super high (SHF)	3 to 30 GHz
Extremely high (EHF)	30 to 300 GHz
Infrared or heat	300 GHz to 430 THz
Visible light	430 THz to 1000 THz
Ultraviolet	1000 THz to 6000 THz

B. The frequency bands which are used for most radio communications are the radio frequency (RF) and microwave frequency bands.

	Frequency	Wavelength	Band
Radio	3 — 30 kHz	100 — 10 kilometer	VLF
	30 — 300 kHz	10 — 1 kilometer	LF
	0.3 — 3.0 MHz	1000 — 100 meter	MF
	3 — 30 MHz	100 — 10 meter	HF
	30 — 300 MHz	10 — 1 meter	VHF
	300 — 1000 MHz	1 — 0.3 meter	UHF
Microwave	1.0 — 2.0 GHz	30 — 15 cm	L-band
	2.0 — 4.0 GHz	15 — 7.5 cm	S-band
	4.0 — 8.0 GHz	7.5 — 3.75 cm	C-band
	8.0 — 12.0 GHz	3.75 — 2.5 cm	X-band
	12.0 — 18.0 GHz	2.5 — 1.67 cm	Ku-band
	18.0 — 27.0 GHz	1.67 — 1.11 cm	K-band
	27.0 — 40.0 Ghz	1.11 — 0.75 cm	Ka-band
	40.0 — 300 Ghz	750 — 100 mm	Millimeter

INFORMATION SHEET

VIII. Recommended commercial radio operator licensing and certification agencies

A. Electronics Technicians Association, International (ETA), P.O. Box 1258, Ames, Iowa, 50010; offers four levels of certification including

1. Associate
2. Journeyman
3. Senior
4. Master

B. International Society of Certified Electronic Technicians (ISCET), 2708 W. Berry Street, Fort Worth, Texas, 76109; offers two levels of certification testing

1. Associate level
2. Journeyman level

C. National Association of Business Educational Radio (NABER), P.O. Box 19164, Washington, D.C. 20036; offers certification tests related to land mobile radio and is considering specialized endorsement.

D. National Association of Radio and Telecommunications Engineers, Inc. (NARTE), P.O. Box 15029, Salem, Oregon, 97309; offers seven levels of certification with endorsements covering specialized categories.

E. National Institute for Certification in Engineering Technologies (NICET), 1420 King Street, Alexandria, VA, 22314; offers three levels of certification which are tied to years of applicable work experience.

F. Society of Broadcast Engineers, Inc. (SBE), P.O. Box 50844, Indianapolis, Indiana, 46250; offers a certification program designed for broadcast engineers.

IX. Catalogs, publications, and their uses

A. User manuals supplied with equipment provide general unpacking, set-up, and operating instructions.

B. Technical manuals sometimes come with original equipment, but frequently have to be purchased from the manufacturer.

(NOTE: A technical manual is necessary to properly service and repair almost any type of equipment.)

C. Maintenance manuals are usually extended technical manuals that contain specific information about testing, hooking up instrumentation equipment, disassembly and reassembly of components, and repair hints and procedures.

INFORMATION SHEET

D. Photofacts (registered trademark of Howard W. Sams and Co., Inc., Indianapolis, Indiana) are available for selected equipment and give a variety of valuable information.

E. Catalogs which are supplied by manufacturers, parts wholesalers and retailers provide a source for repair parts.

F. Service information manuals consisting of:

1. List of preliminary service checks
2. Schematics including standard notations for waveforms, voltages and stage identification
3. Step-by-step troubleshooting guide
4. A component by component parts list
5. Photographs with map-type grid references to help locate components quickly
6. Step-by-step alignment procedures

ORIENTATION
UNIT I

ASSIGNMENT SHEET #1 — EXPLORE CAREERS IN ELECTRONIC COMMUNICATIONS

NAME ______________________________ SCORE ______________

Directions: Make an appointment to interview an industry representative, such as a personnel director, who can provide information about careers in electronic communications. Then answer the following questions.

1. What career opportunities are available in your area?

____

____

____

____

2. What are the requirements for each career?

____

____

____

____

3. What are the salaries/benefits/advancement opportunities in these positions?

____

____

____

____

4. Which career would you like to pursue based on the information collected? Why?

____

____

____

____

ORIENTATION
UNIT I

NAME ______________________ SCORE ____________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. 1000 hertz

_____b. 1,000,000 hertz

_____c. 1,000,000,000 hertz

_____d. 1,000,000,000,000 hertz

_____e. The practice of the transfer of information by any electromagnetic means, such as wire, radio waves, or light waves

_____f. Communication by means of a telecommunications system that transmits documentary matter, such as images or printed matter, and reproduces it at a distant location

_____g. The distance between two successive peaks of a signal

_____h. Communication by a telecommunications system that is designed to transmit sound

_____i. A station open to public correspondence; organization providing general service to the public for a fee

1. Common-carrier
2. Gigahertz
3. Kilohertz
4. Megahertz
5. Telecommunications
6. Telegraphy
7. Telephony
8. Terahertz
9. Wavelength

2. Complete the following statements concerning general safety practices for accident prevention by inserting the word(s) that best complete(s) each statement.

a. Be knowledgeable in __________ and __________ __________ procedures.

b. Know the location of the nearest __________ ,and how to use it.

c. Know the location of the nearest __________ where emergency numbers can quickly be found.

d. Know the location of the __________ __________ kit.

TEST

e. Wear safety glasses in all ____________ areas.

f. Know the emergency evacuation route to use for a ____________ emergency.

g. Know the emergency evacuation routine for a tornado alert and the location of the nearest ____________ ____________.

h. Use all tools and equipment for their ____________ ____________ only.

i. ____________ rings, necklaces, and any metallic jewelry that might inadvertently come in contact with energized areas.

j. Do not wear loose clothing around ____________ machines.

k. Know all special ____________ procedures for your work area and adhere to them.

l. Synthetic clothing should not be worn where ____________ ____________ may be a problem.

m. Report all ____________ to your instructor immediately.

3. Complete the following statements concerning events in the history of electronics by inserting the word(s) that best complete(s) each statement.

a. In 1835, Samuel Morse used a ____________ system to send dots and dashes to communicate from one location to another.

b. In 1858, a ____________ telegraph cable was completed.

c. In 1875, Alexander Graham Bell demonstrated the ____________.

d. In 1887, Heinrich Hertz demonstrated the transmission and reception of ____________.

e. In 1901, Marconi successfully used a wireless telegraph to transmit Morse code across the ____________ ocean.

f. In 1907, Lee ____________ developed the triode vacuum tube.

g. In 1947, Bell Laboratories developed the ____________.

h. In 1956, the first transatlantic ____________ cable service was completed.

i. In 1959, the ____________ company developed the planar-integrated circuit.

j. In 1970, Intel Corporation developed the ____________ integrated circuit.

TEST

4. Name five types of industries in which careers in electronic communications are available.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

5. Complete the following statements concerning regulating agencies for electronic communications by inserting the words which best complete each statement.

   a. The ____________ ____________ ____________ holds the World Administrative Radio Conference every twenty years to formulate agreement on frequency uses.

   b. Various bodies and committees, on behalf of the ____________ ____________ ____________, determine the standards in the United States.

   c. The ____________ ____________ ____________ is the major regulating agency in the USA for radio communications between the 50 states, territories and possessions of the United States and between this country and other countries.

6. Select from the following list major activities of the Federal Communications Commission (FCC) by placing an "X" in the blanks preceding the correct activities.

   _____a. Allocates bands of frequencies to various radio services

   _____b. Assigns specific frequencies and power to individual stations

   _____c. Regulates various radio services

   _____d. Issues a license to television and radio stations

   _____e. Issues a license to station operators

   _____f. Purchases radio stations

   _____g. Inspects radio stations

   _____h. Creates and modifies the set of rules and regulations for communication by wire, cable, radio, and television

TEST

7. Complete the following statements concerning the bands within the frequency spectrum by inserting the words that best complete each statement.

   a. The frequency spectrum is divided into numerous bands with separate ____________ of ____________ for each designated band.

   b. The frequency bands which are used for most radio communications are the ____________ frequency and ____________ frequency bands.

8. Select from the following list recommended commercial radio operator licensing and certification agencies by placing an "X" in the blanks preceding the correct agencies.

   _____a. Federal Communications Commission

   _____b. Electronics Technicians Association, International

   _____c. International Society of Certified Electronic Technicians

   _____d. National Association of Business Educational Radio

   _____e. National Association of Radio and Telecommunications Engineers, Inc.

   _____f. Society for the Prevention of Telecommunication Technologies

   _____g. Society of Broadcast Engineers, Inc.

9. Complete the following statements concerning catalogs, publications, and their uses by inserting the word that best completes each statement.

   a. ____________ manuals supplied with equipment provide general unpacking, set-up, and operating instructions.

   b. ____________ manuals sometimes come with original equipment, but frequently have to be purchased from the manufacturer.

   c. ____________ manuals are usually extended technical manuals that contain specific information about testing, hooking up instrumentation equipment, disassembly and reassembly of components, and repair hints and procedures.

   d. ____________ (registered trademark of Howard W. Sams and Co., Inc., Indianapolis, Indiana) are available for selected equipment and give a variety of valuable information.

   e. ____________ which are supplied by manufacturers, parts wholesalers, and retailers provide a source for repair parts.

(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

10. Explore careers in electronic communications. (Assignment Sheet #1)

ORIENTATION
UNIT I

ANSWERS TO TEST

1. a. 3
   b. 4
   c. 2
   d. 8
   e. 5
   f. 6
   g. 9
   h. 7
   i. 1

2. a. Safety, first aid
   b. Fire extinguisher
   c. Telephone
   d. First aid
   e. Work
   f. Fire
   g. Storm shelter
   h. Intended purposes
   i. Remove
   j. Turning
   k. Safety
   l. Static electricity
   m. Accidents

3. a. Telegraph
   b. Transatlantic
   c. Telephone
   d. Radio waves
   e. Atlantic
   f. DeForest
   g. Transistor
   h. Telephone
   i. Fairchild
   j. Microprocessor

4. Any five of the following may be listed:

   a. Telephone
   b. Satellite communications
   c. Two-way radio
   d. Broadcast communications
   e. Manufacturing
   f. Military services
   g. Test equipment
   h. Aerospace industries
   i. Aviation industry
   j. Television
   k. Maritime radio
   l. Consumer electronics
   m. Computer telecommunications

ANSWERS TO TEST

5. a. International Telecommunications Union
   b. USA Standards Institute
   c. Federal Communications Commission

6. a, b, c, d, e, g

7. a. Ranges, frequencies
   b. Radio, microwave

8. b, c, d, e, g

9. a. User
   b. Technical
   c. Maintenance
   d. Photofacts
   e. Catalogs

10. Evaluated to the satisfaction of the instructor

SOLDERING AND BONDING TECHNIQUES
UNIT II

UNIT OBJECTIVE

After completion of this unit, the student should be able to analyze PC board repair requirements and accomplish fabrication and repair on communications equipment. Competencies will be demonstrated by completing the assignment sheet, job sheets, and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to soldering and bonding techniques with their correct definitions.
2. List four factors affecting PC board repair.
3. Select true statements concerning types of PC board materials.
4. List three conductor weights commonly used on PC boards.
5. Complete statements concerning PC board construction.
6. Select from a list types of PC board circuitry.
7. Match types of PC board coatings with their correct characteristics.
8. Match PC board coating removal methods with their correct descriptions.
9. List component mounting methods for printed circuit boards.
10. List five specialized tools used in PC board fabrication and repair.

OBJECTIVE SHEET

11. Select true statements concerning soldering/desoldering procedures.
12. List types of electronic connectors.
13. Complete statements concerning repair methods for PC boards.
14. Determine PC board construction. (Assignment Sheet #1)
15. Demonstrate the ability to:
    a. Prepare a soldering iron for use. (Job Sheet #1)
    b. Solder electronic components to a PC board. (Job Sheet #2)
    c. Desolder electronic components. (Job Sheet #3)

SOLDERING AND BONDING TECHNIQUES
UNIT II

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate correct solder/desolder methods.
2. Demonstrate correct soldering iron preparation.
3. Discuss where the different levels of soldering are employed.
4. Show students examples of electronic connectors.
5. Show students how to analyze PC boards for correct repair procedures.
6. Demonstrate correct communications equipment repair methods.
7. Show films or tapes on fabrication and repair methods.
8. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Duarte and Duarte. *Electronics Assembly and Fabrication Methods*. Second Edition. New York, NY: McGraw-Hill Book Company, 1973.

B. Sherman, Ken. *Data Communications, A User's Guide*. Second Edition. Reston, VA: Reston Publishing Company, 1985.

C. *Rework and Repair for Electronics*. Laurel, MD: Pace Incorporated, 1983.

D. MIL-S-45743E

E. Hartman, Lonnie. *Basic Electronics*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1986.

F. Vorderstrasse, Ron. *General Electronics Technician*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1986.

SOLDERING AND BONDING TECHNIQUES
UNIT II

INFORMATION SHEET

I. **Terms and definitions**

A. Eyelet — A tubular metal device used on PC boards for through connections

B. Flux — A chemical that cleans metals before or during soldering and chemically acts to aid the fusion process

C. Ground plane — A common ground point for PC board circuitry

D. Laminate — Material pressed into thin sheets constructed in layers

E. Pad — Round terminal connection point on a printed circuit board where component lead wires are attached (Transparencies 1 and 2)

F. Potting — A process of assembling components in some type of container and filling with some type of insulating material

G. Repair - To return an item to its original condition

H. Run — A strip of conductor material adhered to a printed circuit board used for current flow (Transparencies 1 and 2)

I. Solder — A soft metal alloy of tin (Sn) and lead (Pb) used for plating and fusing metals together

J. Solder joint — A junction ~~of two~~ or more metals, fused with solder

K. Through connector — A copper coating lining the hole on a PC board for electrical connection

L. Voltage plane — A common voltage point for PC board circuitry

M. Wicking — The ability of solder to travel up the conductors of a wire or braid by capillary action during the process of heating

N. Wrist strap — A grounding strap connected to the technician's wrist and to a ground such as earth to divert static electricity from the electronic components

II. **Factors affecting PC board repair**

A. PC board materials

B. PC board construction

INFORMATION SHEET

C. PC board conductors

D. PC board circuitry

III. Types of PC board materials

A. Epoxy glass — Laminated epoxy and glass fiber producing a very rigid board

B. Phenolic resin — A construction of laminated sections of cotton or paper impregnated with a phenolic resin and used with moderate temperatures

C. Ceramic — White or light tan flexible board designed for use with very high temperatures

D. Mylar flex — A very thin flexible material which may be damaged by too much pressure applied by a soldering iron

IV. Conductor weights commonly used on PC boards

(NOTE: Ounce rating is based on the weight of a square foot of material.)

A. 2 oz. conductor—.0028 inches

B. 1 oz. conductor—.0014 inches

C. 1/2 oz. conductor—.0007 inches

(NOTE: Conductors are usually copper or silver but can be of other materials. The conductor runs are very thin and can be damaged by excessive heat or pressure from soldering irons.)

V. PC board construction

A. Single clad — Conductor runs located on only one side of the PC board (Transparency 1)

B. Double clad — Conductor runs located on both sides of the PC board (Transparency 2)

C. Multi-layer boards — Conductor runs located on both sides with layers of conductors sandwiched inside the boards

VI. Types of PC board circuitry (Transparencies 2 and 3)

A. Conductor runs

B. Conductor pads

INFORMATION SHEET

C. Ground planes

D. Voltage planes

E. Unsupported holes

F. Through connectors

G. Eyelets (funnelets)

H. Binding posts

I. Terminals

VII. Types of PC board coatings and their characteristics

A. Acrylics (varnished) — Coating derived from a compound of hydrogen cyanide and acetylene which is now seldom used

B. Epoxy resin — Compound of specific atoms joined together to form a resin, then used for electronic coatings; was one of the most common, but is now being replaced

C. Polyurethane — A specific type of synthetic rubber polymer replacing epoxy resin, and it may be thick or thin, hard or soft

D. RTV silicone — Synthetic rubber compound primarily used for potting submodules

E. Paralene — New compound developed basically for electronics and is a thin, hard coating

VIII. PC board coating removal methods

A. Solvent — Chemical used to dissolve thin coatings

(NOTE: Xylene is a popular solvent. Do not use harsh chlorine-based solvents.)

B. Abrasion — A primary method for thin coatings where the coating is mechanically scraped off

C. Hot air jet — By controlling the air temperature, this can also be used to remove thin coatings

INFORMATION SHEET

D. Thermal parting — Uses tips of various shapes and is temperature controlled; used on thick coatings

(NOTE: The tips should not have sharp edges. Also, soldering iron tips should not be used as the high temperature and sharp edges will damage the board.)

E. Freon TF — Used for silicone coatings as it softens and expands the rubber and loosens its bond during soaking

IX. **Component mounting methods for printed circuit boards** (Transparency 4)

A. Straight through

B. Clinched lead

C. Semi-clinched lead

D. Swaged/spaded

E. Surface mount

F. Offset pad mounting

X. **Specialized tools used in PC board fabrication and repair**

A. Thermal parting tool

B. Hot air jet

C. Desoldering tool

D. PC board vise

E. Soldering iron

XI. **Soldering/desoldering procedures**

A. Regulations controlling soldering

1. MIL-S-45743E is a government specification which is now being followed by most industries.

2. Detailed drawings often have specific soldering procedures which must be followed.

INFORMATION SHEET

B. Laboratory conditions

1. Temperature should be kept at 75° ± 9°F. (24° ± 5° C)

2. Relative humidity should not exceed 65%.

   (NOTE: If humidity should be 30% or lower, precautions must be taken due to static electrical charges.)

3. Contaminants, both airborne and solids such as dust and food, are not permitted in the soldering area.

C. Soldering iron preparation

1. Check tip and heating element for secure connection.

2. Check tip for excessive buildup or damage, and replace if necessary.

   (NOTE: Many of the new tips should not be filed, only wiped clean.)

3. Plug in soldering iron and apply a thin coating of solder (tinning).

   (NOTE: Excessive, continued heat can damage the tip and cause repreparation of the tip.)

D. Component installation (Transparency 5)

1. Install component on PC board according to the specific industrial specifications.

2. Solder component to PC board.

   (NOTE: Be sure both elements are heated properly, apply solder to the elements only, not the tip, and use minimum solder. Soldering should be accomplished in 3 seconds or less.)

3. Cut off excessive conductor as close as possible to the PC board.

4. Clean residue from PC board using proper techniques.

E. Component removal (Transparency 5)

1. Locate component to be removed.

2. Analyze the PC board as to type of material, construction, conductors, and circuitry.

3. Check the solder joint for coating material and remove from area as necessary.

INFORMATION SHEET

4. Remove solder using solder braid or solder suction device.

   (NOTE: Solder removal should be accomplished within three seconds per terminal.)

5. Carefully remove component from circuit board.

XII. Types of electronic connectors

A. Solder joint (Transparency 5)

B. Solder terminals (Transparency 6)

C. Solder lugs (Transparency 7)

D. Wire lacing (Transparency 7)

E. Ty wrapping (Transparency 7)

F. Static protection (Transparency 7)

G. Edge connectors (Transparency 8)

H. Pin connectors (Transparency 8)

I. Wire wraps (Transparency 6)

   1. Standard wrap

   2. Modified wrap

XIII. Repair methods for PC boards

(NOTE: Due to static electricity being damaging to components, wrist straps should be worn.)

A. Wicking is a method of solder removal using a solder braid and is best used only on surface joints and single clad PC boards.

B. The vacuum method uses a bulb or pump to suction the solder from the joint and is again best used on surface connections.

C. The heat and pull method of component removal primarily applies to hot air bonding techniques and may leave solder in the hole and cause possible damage due to excessive heat.

D. Solder flow bath method of DIP removal heats all leads simultaneously and component is removed.

INFORMATION SHEET

E. The solder extraction method uses a suction device and can be used on all types of solder connections.

F. Conformal coatings must be removed and are done so using methods explained in Objective VIII.

G. A small break in a conductor run should be repaired by a small piece of flattened conductor or repair material soldered to the run using the surface or through board methods.

H. Damaged pads are replaced by redrilling the hole, adding a repair pad, and fastening by inserting an eyelet.

I. Burned PC boards are repaired by removing charred area and filling with fiberglass.

(NOTE: In case of excessive damage, it may be more economical to replace the PC board.)

J. Larger burned areas are repaired by removing a section of PC board and replacing with a new section and epoxied in place.

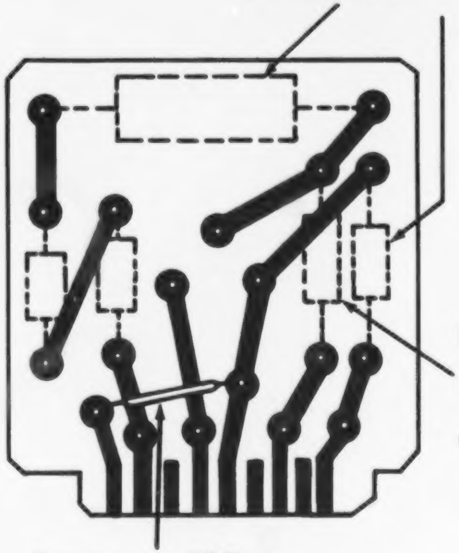
K. Delaminations or blisters are separations between sheets of the PC board and are repaired by injecting epoxy into the blister.

L. Lifted edge connectors can be repaired by applying epoxy and clamping with teflon blocks.

M. Damaged edge connectors must be removed and replaced with repair material.

N. Worn or gold plated edge connectors must be replated through electroplating.

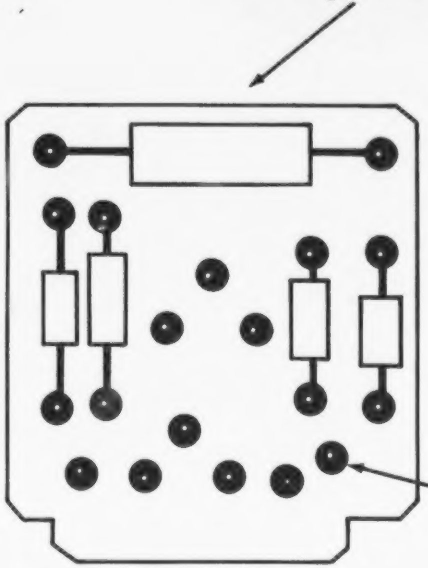
Printed Circuit Board and Components (Single Clad)



Components Reverse Side of Board

Component Used as Jumper

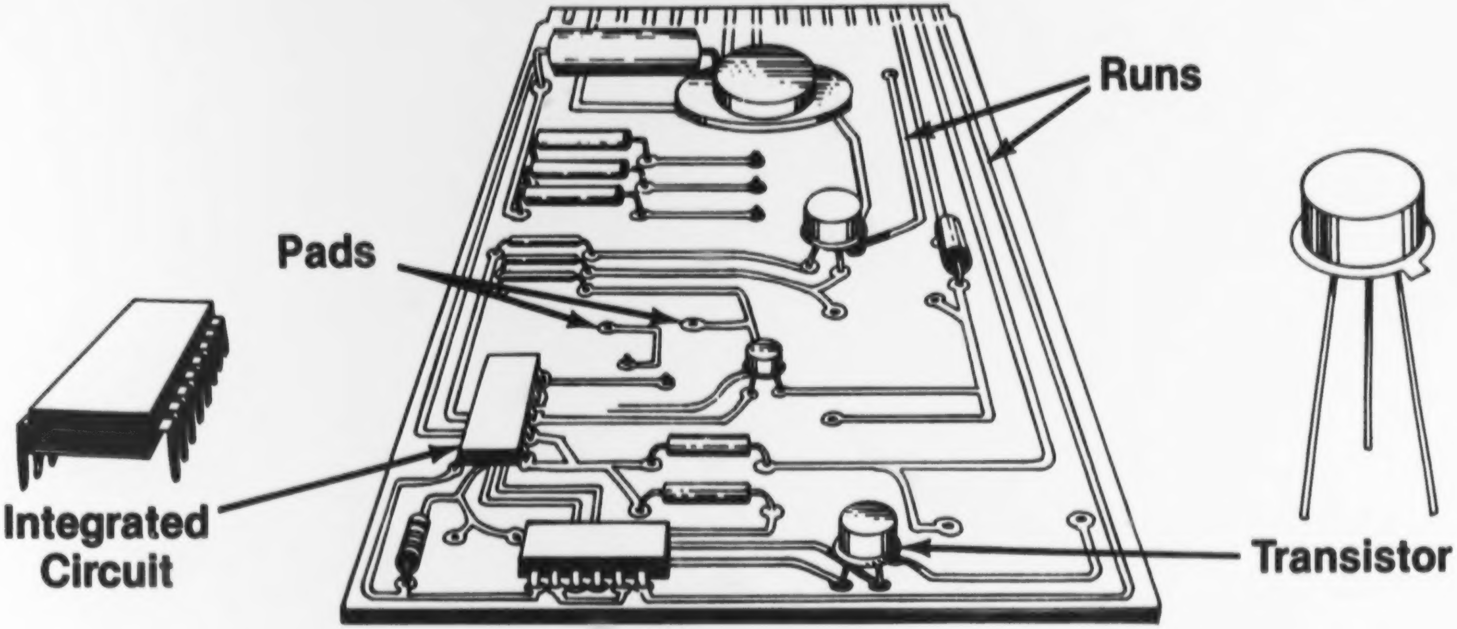
Jumper Wire



Components

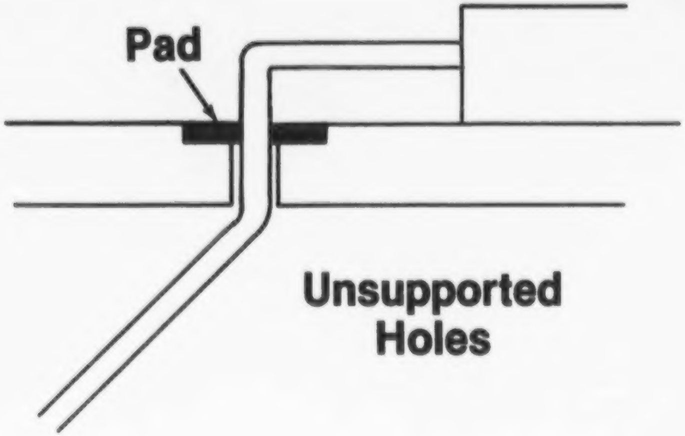
Pads

Printed Circuit Board and Components (Double Clad)

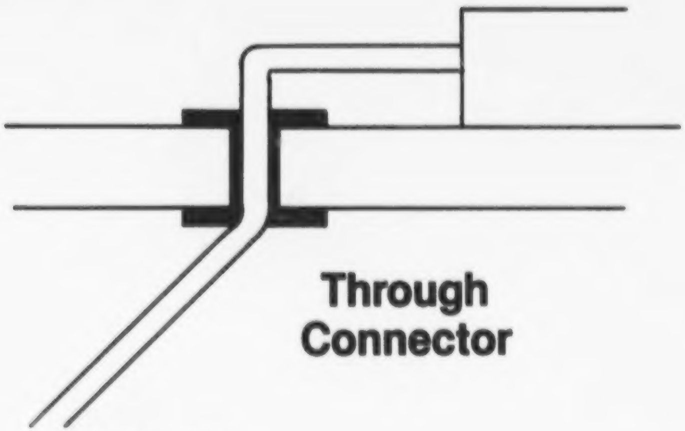

Runs
Pads
Transistor
Integrated Circuit

Both Sides Are Similar to This

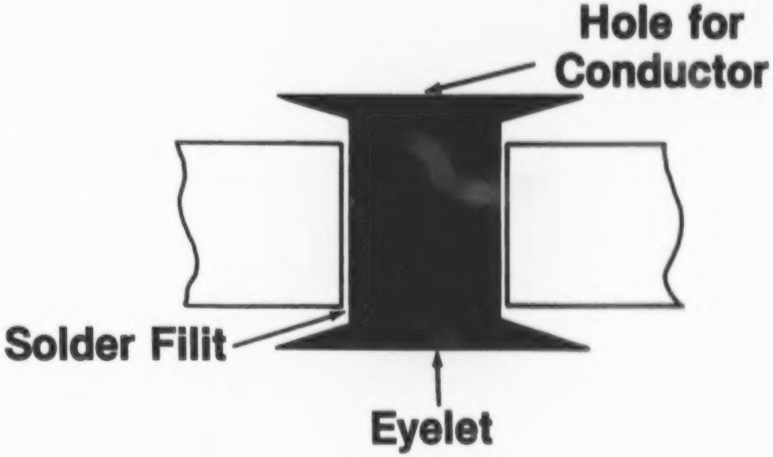
Hole Connectors



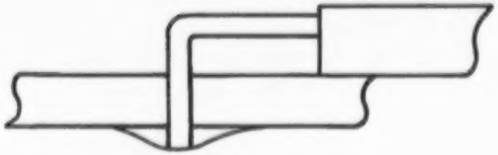
Unsupported Holes



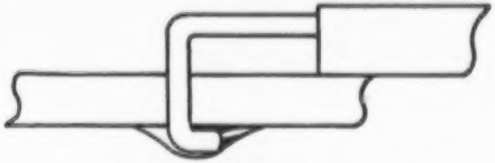
Through Connector


Hole for Conductor
Solder Filit
Eyelet

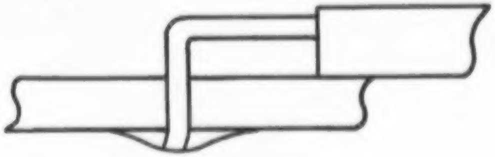
Component Mounting Methods



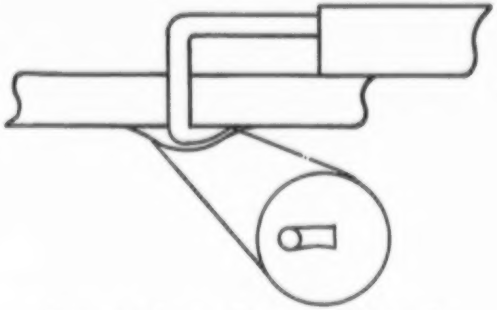
Straight Through



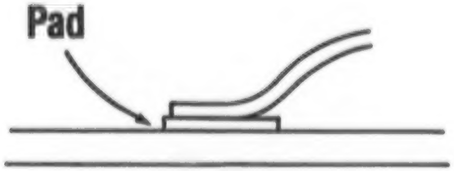
Clinched Lead



Semi-Clinched Lead

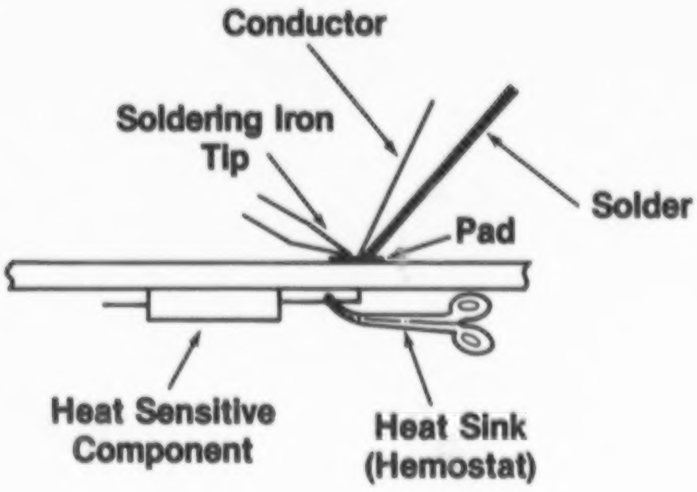


Swaged or Spaded Lead

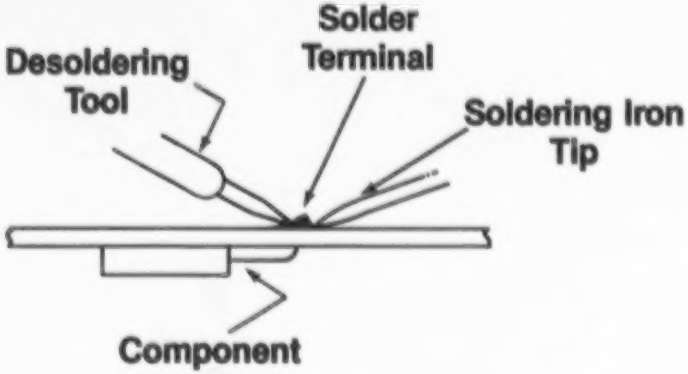


Surface Mount
(Flatpack)

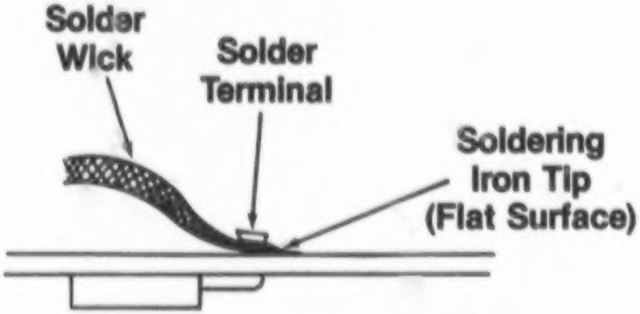
Soldering/Desoldering


Conductor
Soldering Iron Tip
Solder
Pad
Heat Sensitive Component
Heat Sink (Hemostat)

Soldering with Heat Sink

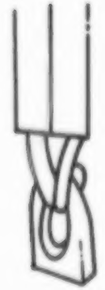

Desoldering Tool
Solder Terminal
Soldering Iron Tip
Component

Desoldering with Vacuum

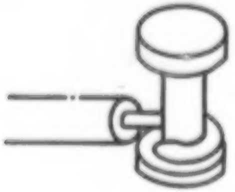

Solder Wick
Solder Terminal
Soldering Iron Tip (Flat Surface)

Desoldering with Solder Wick

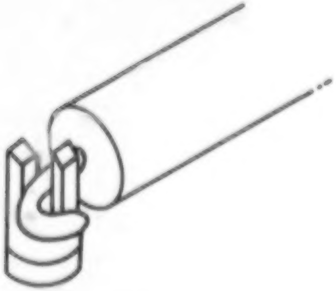
Electronic Connectors



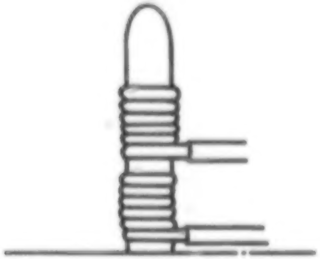
Eyelet Terminal



Solder Terminal



Bifurcated Terminal

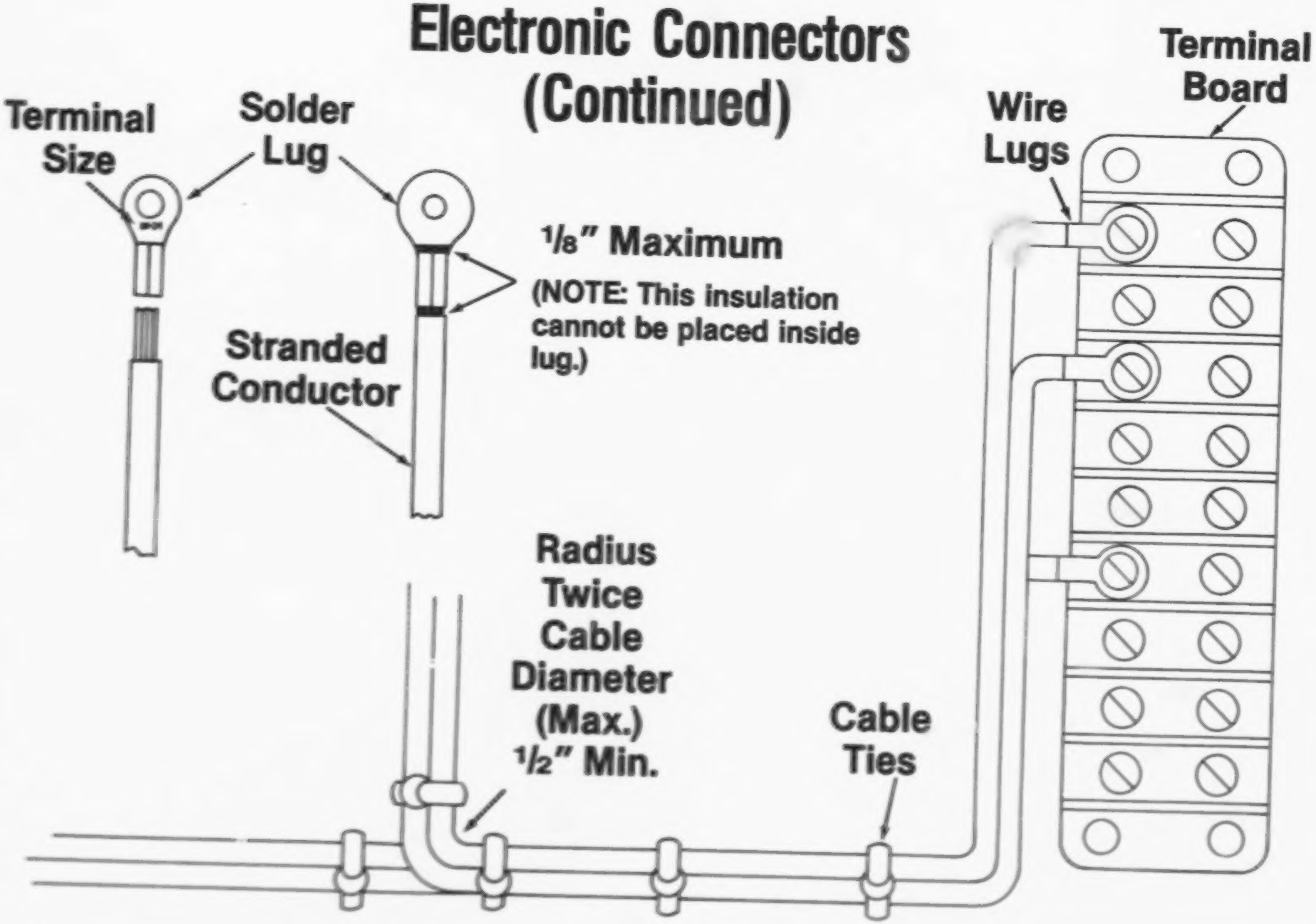


Wire Wrap

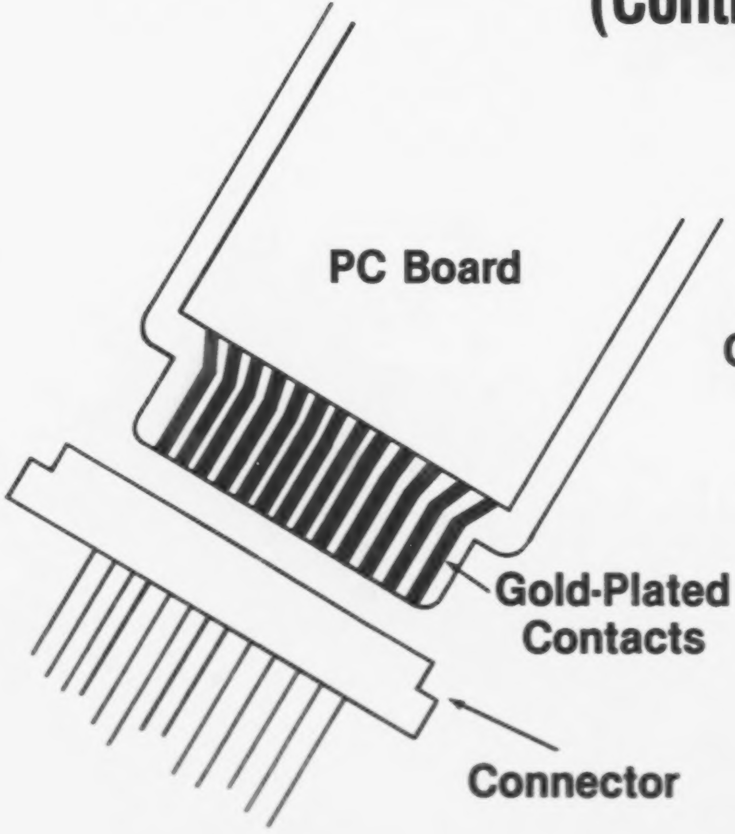
TM 6

CE-43

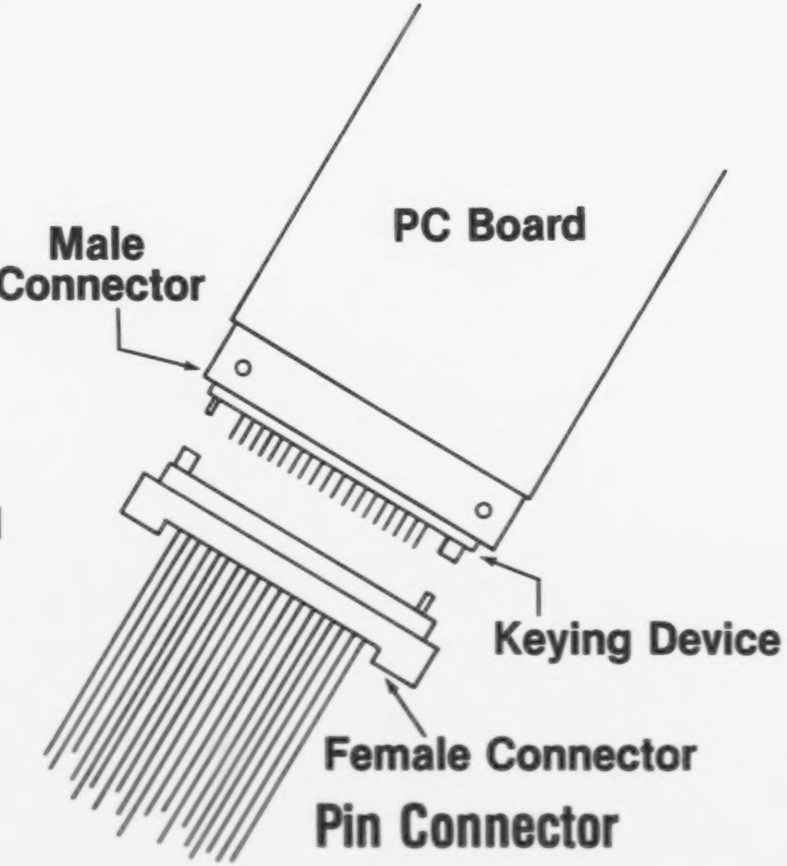
Electronic Connectors (Continued)


Terminal Size
Solder Lug
1/8" Maximum
(NOTE: This insulation cannot be placed inside lug.)
Stranded Conductor
Wire Lugs
Terminal Board
Radius Twice Cable Diameter (Max.) 1/2" Min.
Cable Ties

Electronic Connectors (Continued)


PC Board
Gold-Plated Contacts
Connector

Edge Connector


Male Connector
PC Board
Keying Device
Female Connector

Pin Connector

SOLDERING AND BONDING TECHNIQUES
UNIT II

ASSIGNMENT SHEET #1 — DETERMINE PC BOARD CONSTRUCTION

NAME ______________________________ SCORE ______________

(NOTE: In order to repair a PC board, the construction must be determined in order to repair and not damage the board.)

Directions: Study a PC board designated by your instructor, then determine its construction and indicate your findings below.

1. Circuit board material

   ☐ Epoxy glass

   ☐ Phenolic resin

   ☐ Ceramic

   ☐ Mylar flex

   ☐ Other

2. Circuit construction

   ☐ Single clad

   ☐ Double clad

   ☐ Multi-layer board

   ☐ Other

3. Component type

   ☐ Conductor leads

   ☐ DIP

   ☐ Transistor

   ☐ Multi-pin

ASSIGNMENT SHEET #1

4. Solder joint type

   ☐ Straight through

   ☐ Clinched lead

   ☐ Semi-clinched lead

   ☐ Swaged/spaded

   ☐ Surface mount

   ☐ Offset pad mount

   ☐ Terminal

5. Conformal coating

   ☐ Acrylics

   ☐ Epoxy resin

   ☐ Polyurethane

   ☐ RTV silicone

   ☐ Paralene

   ☐ None

6. Component to be removed ____

7. The ☐ PC board, ☐ component must be saved.

SOLDERING AND BONDING TECHNIQUES
UNIT II

JOB SHEET #1 — PREPARE A SOLDERING IRON FOR USE

A. Equipment and materials needed

1. Soldering iron (20-30 Watts)
2. Soldering iron holder
3. Sponge
4. Long nose pliers
5. Diagonal pliers
6. 63/37 resin core solder
7. Solder remover
8. Small, fine file
9. Printed circuit board with components
10. Extra components
11. Safety goggles/glasses

B. Procedure

1. Put on safety goggles.
2. While the soldering iron is cool, inspect the tip for corrosion and type of construction.
3. If the tip is corroded, pitted, or in need of reshaping, replace it.
4. Place the soldering iron in the holder and connect the power cord.
5. When the soldering iron tip reaches the lowest temperature required to melt solder, apply the solder to the tip's working surfaces.
6. When you are satisfied that the soldering iron is correctly prepared, unplug the iron and show it to your instructor.
7. Return equipment and materials to their proper storage location.

SOLDERING AND BONDING TECHNIQUES
UNIT II

JOB SHEET #2 — SOLDER ELECTRONIC COMPONENTS TO A PC BOARD

A. Equipment and materials needed

1. Printed circuit board—single clad
2. Electronic components—one non-heat sensitive, one heat sensitive
3. Solder
4. Soldering iron
5. Heat sink
6. Tools—other standard electronic tools
7. Safety goggles
8. Static protection equipment (as required)

B. Procedure

1. Put on safety goggles.
2. Check PC board for location of component installation.

   (NOTE: If using a used PC board, be sure the pads and runs are not damaged and are secured to the PC board. The connection points should also be clean and free from all solder.)

3. Install the non-heat sensitive component on the non-conductive side of the PC board.

   (NOTE: The leads of the component, if flush mounted, should be bent as shown in Transparency 4.)

4. Slightly bend the leads once they pass through the circuit board to hold the component in place.

   (NOTE: Other mounting procedures may be used if specified by your instructor. See Transparency 4.)

5. Using the correctly prepared soldering iron, solder all conductors.

   (NOTE: Minimum solder, enough for a good connection, should be applied.)

6. Cut off excess conductor leads.

JOB SHEET #2

7. Reflow the solder connection to allow the flow of solder to cover the conductor completely.

8. Clean residue from PC board.

9. When completed, have instructor inspect the solder connections.

10. Check PC board for location of component installation again.

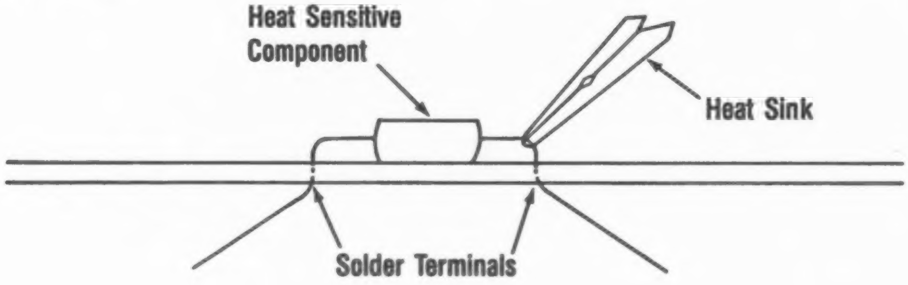
11. Install the heat sensitive component on the non-conductive side of the PC board.

    (NOTE: If a double clad board should be used, install the component on the side opposite the solder point.)

12. Bend the leads once they pass through the PC board according to the method being used. (See Transparency 4)

13. Connect a heat sink on the conductor being soldered between the solder point and the component.

    EXAMPLE:



14. Solder the conductor containing the heat sink.

    (NOTE: The heat sink is only used to protect the heat sensitive component. Excessive heat can damage the component if the soldering iron is left on the terminal for an excessive amount of time. Do not remove the heat sink until the terminal has cooled.)

15. Again be sure the terminal is complete and the solder flow is over the conductor lead.

16. When you have completed all solder terminals on the component, have your instructor inspect the PC board.

17. Return equipment and materials to their proper storage location.

SOLDERING AND BONDING TECHNIQUES
UNIT II

JOB SHEET #3 — DESOLDER ELECTRONIC COMPONENTS

A. Equipment and materials needed

1. Printed circuit board—single clad
2. Solder
3. Soldering iron
4. Heat sink
5. Tools—other standard electronic tools
6. Safety goggles
7. Static protection equipment (as required)

B. Procedure

1. Put on safety goggles.
2. Check component board for component to be removed.
3. Determine PC board construction and determine correct desoldering techniques.

   (NOTE: Refer to Assignment Sheet #1.)
4. Be sure soldering iron has been properly prepared.
5. Remove solder from terminals.

   (NOTE: Do not try to remove component prior to solder removal.)
6. Carefully remove component from PC board.

   (NOTE: If component does not release, lightly apply iron tip to conductor while gently trying to remove component.)
7. Once component has been removed, clean PC board, pad, and conductor hole in PC board.
8. When you have completed removal, show the component and board to your instructor.
9. Return equipment and materials to their proper storage location.

SOLDERING AND BONDING TECHNIQUES
UNIT II

JOB SHEET #1 PRACTICAL TEST —
PREPARE A SOLDERING IRON FOR USE

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Properly evaluated the tip to determine preparation procedure.	______	______
3. Filed or replaced tip as required.	______	______
4. Properly tinned the prepared tip.	______	______
5. Checked in/put away tools and materials.	______	______
6. Cleaned the work area.	______	______
7. Used proper tools correctly.	______	______
8. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
9. Practiced safety rules throughout procedure.	______	______
10. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Correctly evaluated soldering iron tip	4	3	2	1
Properly prepared tip	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

SOLDERING AND BONDING TECHNIQUES
UNIT II

JOB SHEET #2 PRACTICAL TEST — SOLDER ELECTRONIC COMPONENTS TO A PC BOARD

STUDENT'S NAME ________________________ DATE __________

EVALUATOR'S NAME ________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Properly installed components on PC board.	______	______
3. Properly soldered component connections using correct solder.	______	______
4. Properly soldered both heat sensitive and non-heat sensitive components.	______	______
5. Properly cleaned components.	______	______
6. Properly used a heat sink.	______	______
7. Properly used static protection.	______	______
8. Checked in/put away tools and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Circuit board clean	4	3	2	1
Proper amount of solder applied	4	3	2	1
Proper amount of heat applied	4	3	2	1
Component correctly replaced	4	3	2	1

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

SOLDERING AND BONDING TECHNIQUES
UNIT II

PRACTICAL TEST JOB SHEET #3 — DESOLDER ELECTRONIC COMPONENTS

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Properly prepared soldering iron tip for use.	______	______
3. Determined components to be removed.	______	______
4. Determined correct desoldering technique.	______	______
5. Properly removed the solder from terminals.	______	______
6. Properly removed component from PC board.	______	______
7. Properly cleaned the board, runs, and pads.	______	______
8. Properly used static protection.	______	______
9. Checked in/put away tools and materials.	______	______
10. Cleaned the work area.	______	______
11. Used proper tools correctly.	______	______
12. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
13. Practiced safety rules throughout procedure.	______	______
14. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
PC board free of damage	4	3	2	1
Parts free of damage	4	3	2	1
Surface ready for component replacement	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

SOLDERING AND BONDING TECHNIQUES
UNIT II

TEST

NAME ____________________ SCORE ____________________

1. Match the terms on the right with their correct definitions.

_____a. The ability fo solder to travel up the conductors of a wire or braid by capillary action during the process of heating

_____b. Material pressed into thin sheets constructed in layers

_____c. A copper coating lining the hole on a PC board for electrical connection

_____d. A soft metal alloy of tin (Sn) and lead (Pb) used for plating and fusing metals together

_____e. A strip of conductor material adhered to a printed circuit board used for current flow

_____f. A tubular metal device used on PC boards for through connections

_____g. A common ground point for PC board circuits

_____h. A process of assembling components in some type of container and filling with some type of insulating material

_____i. A chemical that cleans metals before or during soldering and chemically acts to aid the fusion process

_____j. A common voltage point for PC board circuitry

_____k. A junction of two or more metals, fused with solder

_____l. A grounding strap connected to the technician's wrist and to a ground such as earth to divert static electricity from the electronic components

1. Eyelet
2. Flux
3. Ground plane
4. Laminate
5. Pad
6. Potting
7. Repair
8. Run
9. Solder
10. Solder joint
11. Through connection
12. Voltage plane
13. Wicking
14. Wrist strap

TEST

_____m. To return an item to its original condition

_____n. Round terminal connection point on a printed circuit board where component lead wires are attached

2. List four factors affecting PC board repair.

   a. ____

   b. ____

   c. ____

   d. ____

3. Select true statements concerning types of PC board materials by placing an "X" in the blanks preceding the true statements.

   _____a. Epoxy glass is laminated epoxy and glass fiber producing a very rigid board.

   _____b. A construction of laminated sections of cotton or paper impregnated with epoxy and used with high temperatures is called phenolic resin.

   _____c. Ceramic is a white or light tan rigid board designed for use with moderate temperatures.

   _____d. Mylar flex is a very thin flexible material which may be damaged by too much pressure applied by a soldering iron.

4. List three conductor weights commonly used on PC boards.

   a. ____

   b. ____

   c. ____

5. Complete the following statements concerning PC board construction by inserting the words that best complete each statement.

   a. Single clad refers to conductor runs on ____________ ____________ ____________ of the PC board.

   b. Double clad refers to conductor runs located on ____________ ____________ of the PC board.

   c. ____________ ____________ refer to conductor runs located on both sides with layers of conductors sandwiched inside the boards.

TEST

6. Select from the following list types of PC board circuitry by placing an "X" in the blanks preceding the correct types.

_____a. Offset pad

_____b. Conductor runs

_____c. Conductor pads

_____d. Ground planes

_____e. Sandwich planes

_____f. Voltage planes

_____g. Unsupported holes

_____h. Through connectors

_____i. Eyelets (funnelets)

_____j. Terminals

7. Match types of board coatings on the right with their correct characteristics.

_____a. New compound developed basically for electronics and is a thin, hard coating

_____b. A specific type of synthetic rubber polymer replacing epoxy resin, and it may be thick or thin, hard or soft

_____c. Coating derived from a compound of hydrogen cyanide and acetylene which is now seldom used

_____d. Compound of specific atoms joined together to form a resin, then used for electronic coatings; was one of the most common but is now being replaced

_____e. Synthetic rubber compound primarily used for potting submodules

1. Acrylics
2. Epoxy resin
3. Paralene
4. Polyurethane
5. RTV silicone

TEST

8. Match PC board coating removal methods on the right with their correct descriptions.

_____a. By controlling the air temperature, this can also be used to remove thin coatings

_____b. Uses tips of various shapes and is temperature controlled; used on thick coatings

_____c. Chemical used to dissolve thin coatings

_____d. A primary method for thin coatings where the coating is mechanically scraped off

_____e. Used for silicone coatings as it softens and expands the rubber and loosens its bond during soaking

1. Solvent
2. Abrasion
3. Hot air jet
4. Thermal parting
5. Freon TF

9. List four component mounting methods for printed circuit boards.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

10. List five specialized tools used in PC board fabrication and repair.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

11. Select true statements concerning soldering/desoldering procedures by placing an "X" in the blanks preceding the true statements.

_____a. MIL-B-44433A is an outdated government specification which is being followed by only a few industries.

_____b. Under laboratory conditions relative humidity should not exceed 85%.

_____c. Contaminants, both airborne and solids such as dust and food, are not permitted in the soldering area.

TEST

_____d. When preparing the soldering iron, check tip and heating element for secure connection.

_____e. Plug in soldering iron and apply a thick coating of solder.

_____f. Install component on PC board according to the specified industrial specifications.

_____g. Cut off excessive conductor as close as possible to the PC board.

_____h. Remove solder using a stiff brush before removing component from circuit board.

12. List six types of electronic connectors.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

13. Complete the following statements concerning repair methods for PC boards by inserting the word(s) that best complete(s) each statement.

a. Wicking is a method of solder removal using a ____________ ____________ and is best used only on surface joints and single clad PC boards.

b. The vacuum method uses a ____________ or ____________ to suction the solder from the joint and is again best used on surface connections.

c. The heat and pull method of component removal primarily applies to hot air bonding technicians and may leave solder in the hole and cause possible damage due to ____________ ____________.

d. ____________ ____________ ____________ method of DIP removal heats all leads simultaneously and component is removed.

e. The ____________ ____________ method uses a suction device and can be used on all types of solder connections.

TEST

f. ____________ coatings must be removed and are done so using methods explained in Objective VIII.

g. A small break in a conductor run should be repaired by a small piece of ____________ ____________ or repair material soldered to the run using the surface or through board methods.

h. Damaged pads are replaced by redrilling the hole, adding a repair ____________ and fastening by inserting an ____________.

i. Burned PC boards are repaired by removing charred area and filling with ____________.

j. Larger burned areas are repaired by removing a section of PC board and replacing with a new section and ____________ in place.

k. Delaminations or blisters are separations between sheets of the PC board and are repaired by injecting ____________ into the blister.

l. Lifted edge connectors can be repaired by applying epoxy and clamping with ____________ ____________.

m. ____________ edge connectors must be removed and replaced with repair material.

n. Worn or gold plated edge connectors must be replated through ____________.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

14. Determine PC board construction. (Assignment Sheet #1)

15. Demonstrate the ability to:

    a. Prepare a soldering iron for use. (Job Sheet #1)

    b. Solder electronic components to a PC board. (Job Sheet #2)

    c. Desolder electronic components. (Job Sheet #3)

SOLDERING AND BONDING TECHNIQUES
UNIT II

ANSWERS TO TEST

1. a. 13
   b. 4
   c. 11
   d. 9
   e. 8
   f. 1
   g. 3
   h. 6
   i. 2
   j. 12
   k. 10
   l. 14
   m. 7
   n. 5

2. a. PC board materials
   b. PC board construction
   c. PC board conductors
   d. PC board circuitry

3. a, d

4. a. 2 oz.
   b. 1 oz.
   c. 1/2 oz.

5. a. Only one side
   b. Both sides
   c. Multi-layer boards

6. b, c, d, f, g, h, i, j

7. a. 3
   b. 4
   c. 1
   d. 2
   e. 5

8. a. 3
   b. 4
   c. 1
   d. 2
   e. 5

ANSWERS TO TEST

9. Any four of the following:

    a. Straight through
    b. Clinched lead
    c. Semi-clinched lead
    d. Swaged/spaded
    e. Surface mount
    f. Offset pad mounting

10. a. Thermal parting tool
    b. Hot air jet
    c. Desoldering tool
    d. PC board vise
    e. Soldering iron

11. c, d, f, g

12. Any six of the following:

    a. Solder joint
    b. Solder terminals
    c. Solder lugs
    d. Wire lacing
    e. Ty wrapping
    f. Static protection
    g. Edge connectors
    h. Pin connectors
    i. Wire wraps

13. a. Solder braid
    b. Bulb, pump
    c. Excessive heat
    d. Solder flow bath
    e. Solder extraction
    f. Conformal
    g. Flattened conductor
    h. Pad, eyelet
    i. Fiberglass
    j. Epoxied
    k. Epoxy
    l. Teflon blocks
    m. Damaged
    n. Electroplating

14. Evaluated to the satisfaction of the instructor

15. Performance skills evaluated to the satisfaction of the instructor

AMPLIFIERS
UNIT III

UNIT OBJECTIVE

After completion of this unit, the student should be able to measure bandwidth, gain, and frequency response of an amplifier, identify classes of amplifiers, and troubleshoot and repair an amplifier. Competencies will be demonstrated by completing the assignment sheet, job sheet, and the unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to amplifiers with their correct definitions.
2. Complete statements concerning basic amplifier principles.
3. Match transistor amplifier configurations with their characteristics.
4. Select true statements related to stabilization of transistor amplifiers.
5. Complete statements related to types of distortion.
6. List four methods of coupling.
7. Select true statements concerning the classes of amplifier operation.
8. Complete statements concerning the fundamentals of harmonic generation.
9. Complete statements concerning the characteristics of narrow-band amplifiers.
10. Match component malfunctions with a list of resulting symptoms.
11. Complete statements concerning feedback considerations in RF amplifiers.

OBJECTIVE SHEET

12. Complete statements concerning the general characteristics of wide-band amplifiers.

13. Complete statements concerning the characteristics of nonsinusoidal waveforms.

14. Complete statements concerning the methods of improving frequency response for broad-band amplifier circuits.

15. Identify component functions and malfunctions in an amplifier circuit. (Assignment Sheet #1)

16. Demonstrate the ability to construct and analyze an audio IC amplifier circuit. (Job Sheet #1)

AMPLIFIERS
UNIT III

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheet.

H. Discuss and demonstrate the procedure outlined in the job sheet.

I. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate alignment of an amplifier.
2. Demonstrate distortion of a waveform.
3. Demonstrate how to measure gain, bandwidth, distortion, and frequency response using available equipment in laboratory.
4. Locate catalogs for replacement parts and show specifications needed for ordering.
5. Demonstrate the use of a spectrum analyzer.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

H. Administer test.

I. Evaluate test.

J. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Schrader, Robert L. *Electronic Communication.* Fifth Edition. New York: McGraw-Hill Book Company, 1985.

B. Floyd, Thomas L. *Electronic Devices.* Columbus, OH: Bell and Howell Co., 1984.

C. Kennedy, George. *Electronic Communication Systems.* Third Edition. New York: McGraw-Hill Book Company, 1985.

AMPLIFIERS
UNIT III

INFORMATION SHEET

I. **Terms and definitions**

A. Buffer — An amplifier circuit used between two stages to reduce the loading effects of one stage on the other

B. Decoupling — Preventing transfer or feedback of energy from one circuit to another

C. Degeneration — The process of returning part of the output of an amplifier back to the input in such a way that it tends to cancel or reduce the input

D. Feedback — The process used to obtain degeneration or regeneration

E. Gain — The amount by which a signal is increased or amplified

F. Neutralization — The process of nullifying the reactive feedback to prevent unwanted oscillations in an amplifier

G. Regeneration — The process of returning part of the output of an amplifier back to the input in such a way that it tends to aid the input

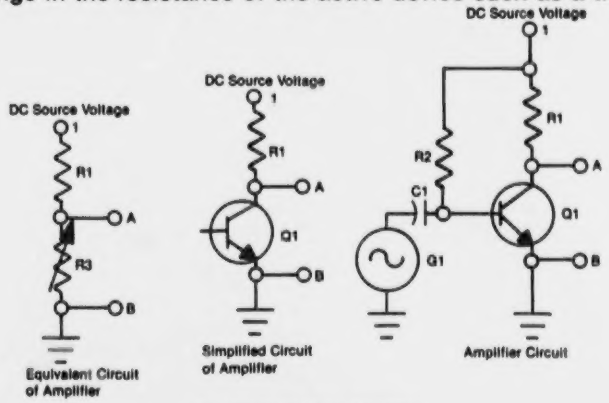
H. Signal — The varying electrical voltage or current that carries desirable intelligence

II. **Basic amplifier principles**

A. Amplifiers are generally classified as power and voltage amplifiers.

B. When it is necessary to increase signal voltage only, the stage is classified as a voltage amplifier.

C. Amplification is dependent on the ability of an input signal to cause a change in the resistance of the active device such as a transistor.



Equivalent Circuit of Amplifier

Simplified Circuit of Amplifier

Amplifier Circuit

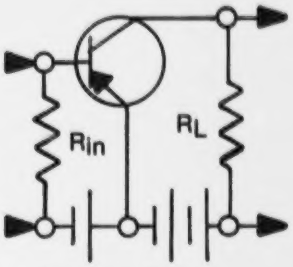
Development of an Amplifier

D. Gain of an amplifier is the ratio of the output to the input.

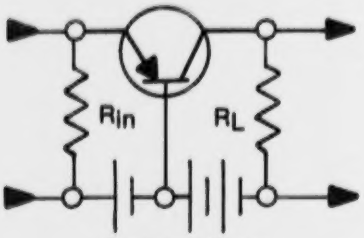
INFORMATION SHEET

III. **Transistor amplifier configurations and their characteristics** (Transparency 1)

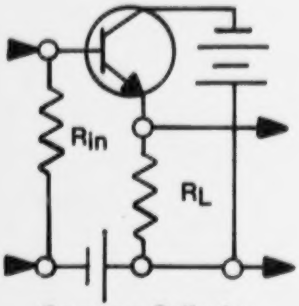
A. Transistor amplifiers have three basic circuit configurations: the common-base, common-emitter, and common-collector.



Common Emitter

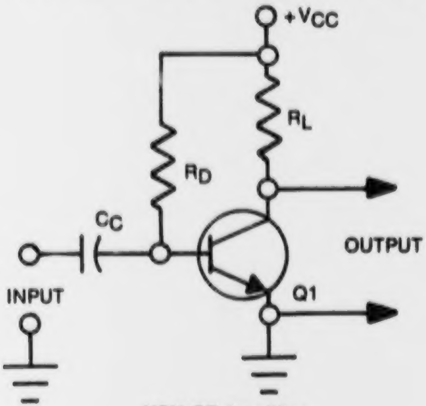


Common Base

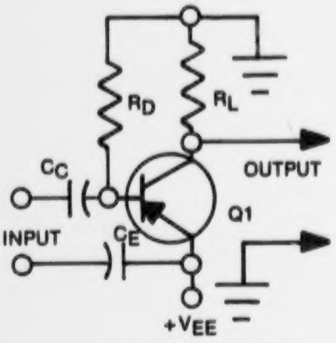


Common Collector

B. The common-emitter configuration uses the emitter as the common reference for the input on the base and the output on the collector.


+VCC
RL
RD
CC
INPUT
OUTPUT
Q1

NPN CE Amplifier

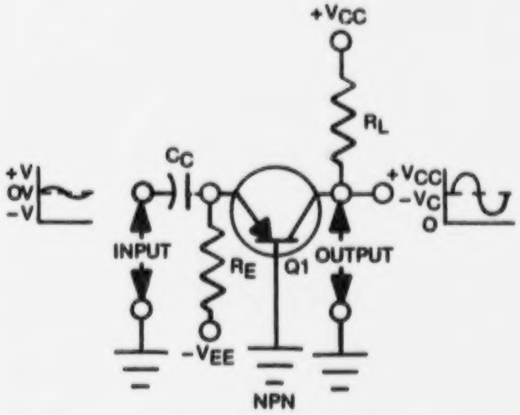

RD
RL
CC
OUTPUT
Q1
INPUT
CE
+VEE

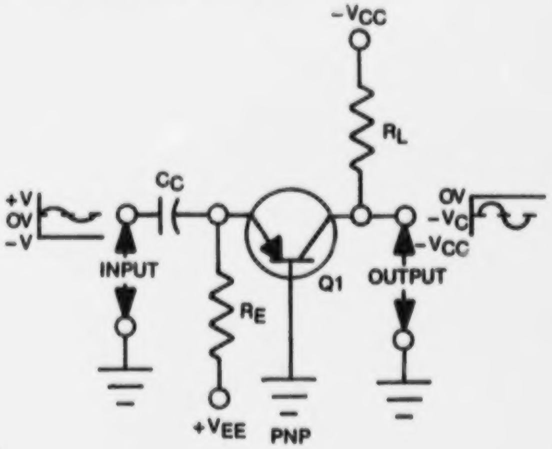
Alternate Circuit (PNP)

1. Relatively high voltage gain
2. High current gain
3. High power gain
4. Medium input impedance
5. Medium output impedance
6. Phase reversal between input and output

INFORMATION SHEET

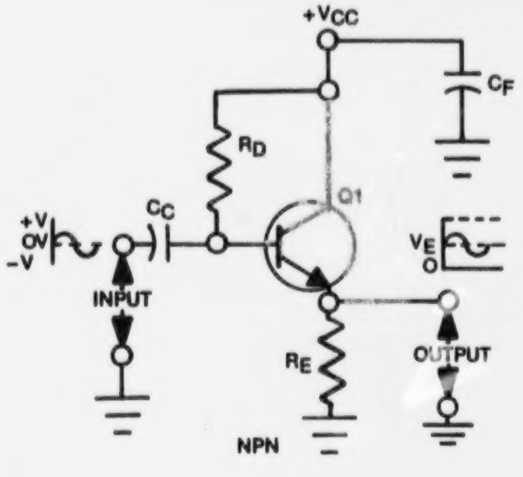
C. The common-base configuration uses the base as the common reference for the input on the emitter and the output on the collector.

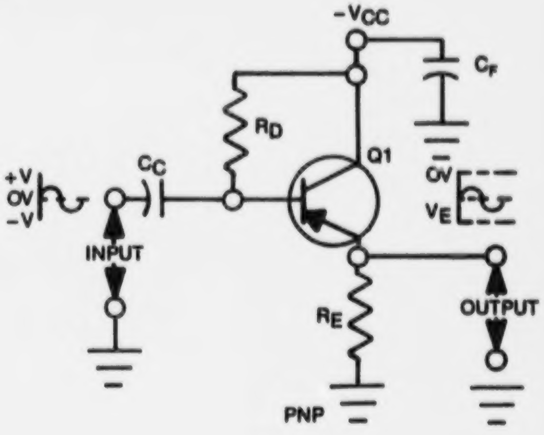

+VCC
RL
CC
+V
OV
-V
+VCC
-VC
O
INPUT
RE
Q1
OUTPUT
-VEE
NPN


-VCC
RL
CC
+V
OV
-V
OV
-VC
-VCC
INPUT
Q1
OUTPUT
RE
+VEE
PNP

1. Relatively high voltage gain
2. Low current gain (less than 1.0)
3. Medium power gain
4. Low input impedance
5. High output impedance
6. Input and output signals in-phase

D. The common-collector configuration (commonly called an emitter-follower) uses the collector as the common reference for the input on the base and output on the emitter. (Transparency 2)


+VCC
CF
RD
Q1
CC
+V
OV
-V
VE
O
INPUT
RE
OUTPUT
NPN


-VCC
CF
RD
Q1
CC
+V
OV
-V
OV
VE
INPUT
RE
OUTPUT
PNP

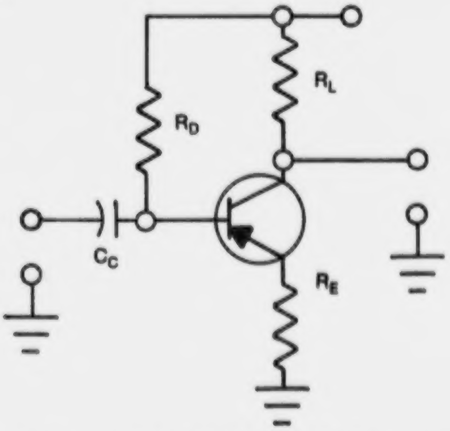
INFORMATION SHEET

1. Low voltage gain (less than unity)
2. High current gain
3. Low power gain
4. High input impedance
5. Low output impedance
6. No phase reversal from input to output

IV. Stabilization of transistor amplifiers

A. The effects of emitter-base junction resistance changes (caused by temperature changes) may be reduced by installing a resistor in series with the emitter.

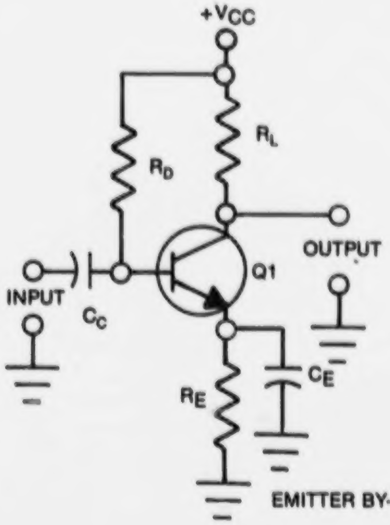
(NOTE: Changes in temperature cause changes in the resistance of the transistor material. These changes affect the DC characteristics of the transistor in its circuit. When circuit changes are made to provide for DC stability, the added circuit components may affect the AC signal characteristics adversely, in which case corrective circuitry must also be added for AC stabilization.)



1. The emitter resistor is often called a swamping resistor because it "swamps out" the effects of changes in the emitter-base junction resistance.
2. The resistor in the emitter circuit introduces degeneration of the AC signal.

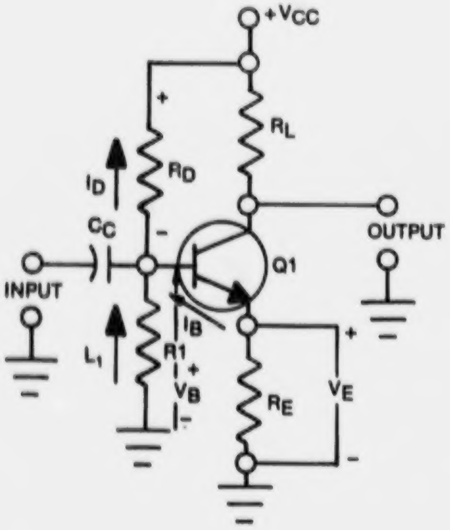
INFORMATION SHEET

B. An emitter "bypass" capacitor is added in parallel to the swamping resistor to enable the AC signal to "see" ground on the emitter thus allowing for temperature stability without degeneration of the signal.


+Vcc
R_L
R_D
OUTPUT
Q1
INPUT
C_C
C_E
R_E

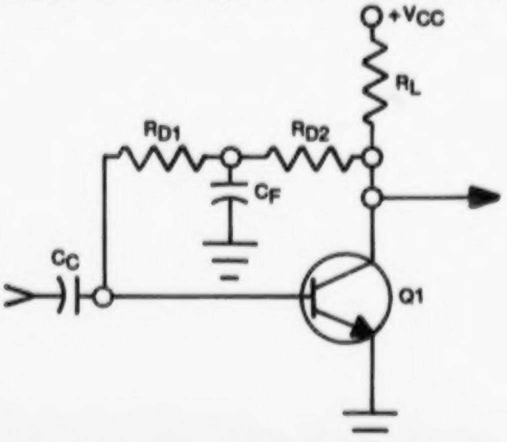
EMITTER BY-PASS CAPACITOR

C. Voltage divider bias stabilization is used to counteract the effects of leakage current between collector and base (Icbo).


+Vcc
+
R_L
I_D
R_D
C_C
-
OUTPUT
Q1
INPUT
I_B
+
L_1
R1
+
V_B
-
V_E
R_E
-

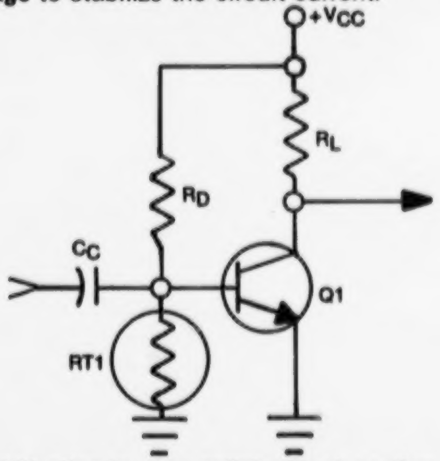
INFORMATION SHEET

D. A self-bias arrangement (or collector feedback) improves thermal stability by providing a form of degenerative feedback from the collector.



(NOTE: The degenerative effects of the feedback on the AC signal may be prevented by modifying the circuit to use two resistors and a capacitor. The resistors and capacitors form a low-pass network preventing ac degeneration while providing DC stabilization.)

E. Thermistor stabilization uses a thermistor with a negative temperature coefficient in the biasing network to cause an automatic variation in the bias voltage to stabilize the circuit current.

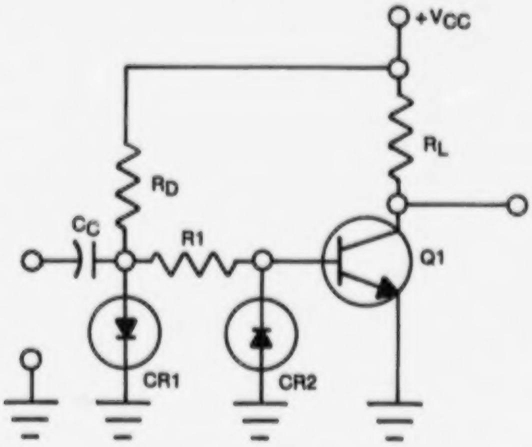


F. Diode stabilization is accomplished by inserting a diode in the biasing network to counteract the variations caused by changes in temperature.

1. A forward-biased diode counteracts the effect of changes in the emitter-base junction resistance.
2. A reverse-biased diode counteracts the adverse effects of changes in Icbo.

INFORMATION SHEET

3. Double-diode stabilization is accomplished by inserting both a reverse-biased and a forward-biased diode in the biasing network thus compensating for the variances in emitter-base junction resistance variances and the changes in Icbo due to temperature.



Double-Diode Stabilization

V. **Types of distortion**

A. Distortion, in general terms, is when the waveshape of the output signal varies in any form with respect to the waveshape of the input signal (except for normal amplitude increase in an amplifier).

B. Amplifiers are subject to four basic forms of distortion: amplitude, frequency, phase, and intermodulation.

C. Amplitude distortion (also known as harmonic distortion) is the result of changing a waveshape so that its amplitude is not proportional to the amplitude of the original waveform and is primarily caused by:

1. Operating the active device in the nonlinear part of its characteristic curve

2. Overdriving the active device

D. Frequency distortion occurs when not all frequencies are amplified equally by the amplifier.

E. Phase distortion, usually caused by reactive components in a circuit, occurs when some frequencies are delayed from input to output resulting in differing amounts of phase-shift for different frequencies.

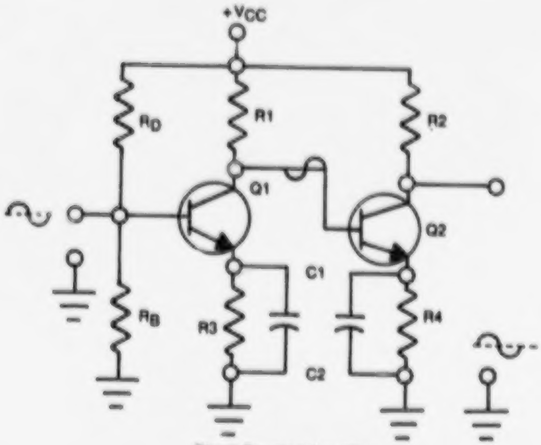
F. Intermodulation distortion occurs when two signals with different frequencies are intermixed, resulting in the production of sum and difference frequencies.

INFORMATION SHEET

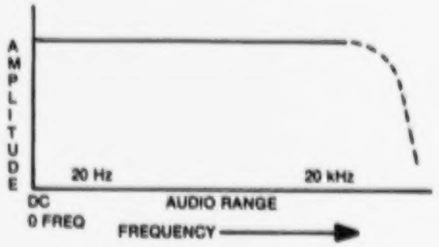
VI. **Methods of coupling**

A. Four methods commonly used to connect amplifier circuits together are direct, resistance-capacitance (RC), impedance (LC), and transformer coupling.

B. When the output of one amplifier has a direct connection to the input of another, the amplifier stages are said to be direct coupled and are often used in low-frequency, audio circuits.

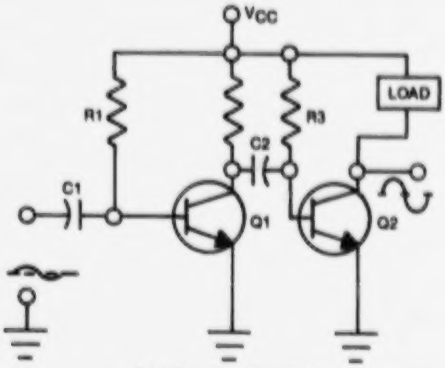


Direct-Coupled Amplifier

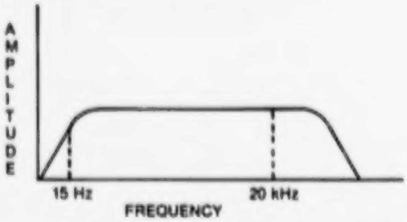


Frequency Response of Direct-Coupled Amplifier

C. RC coupling is widely used in audio frequency circuits and uses a resistor and a capacitor to isolate the DC voltage of one stage from that of another, but transfers the ac signal between stages via the capacitor.



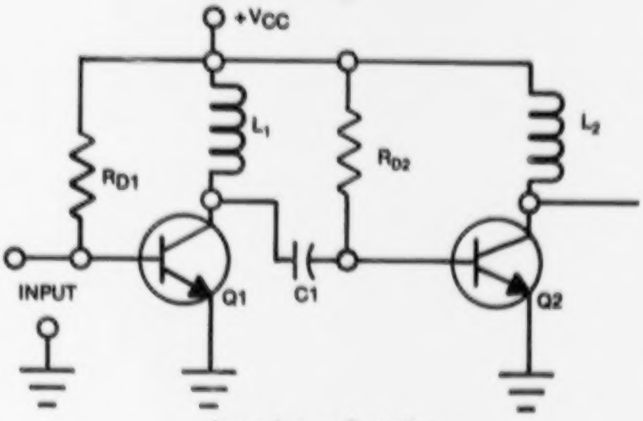
RC Coupled Amplifier



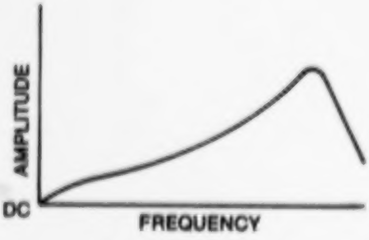
Frequency Response of RC Coupled Amplifier

INFORMATION SHEET

D. Impedance coupling operates similar to RC coupling except that the load resistor is replaced with an inductor and, therefore, may be used for higher frequencies above the AF range.

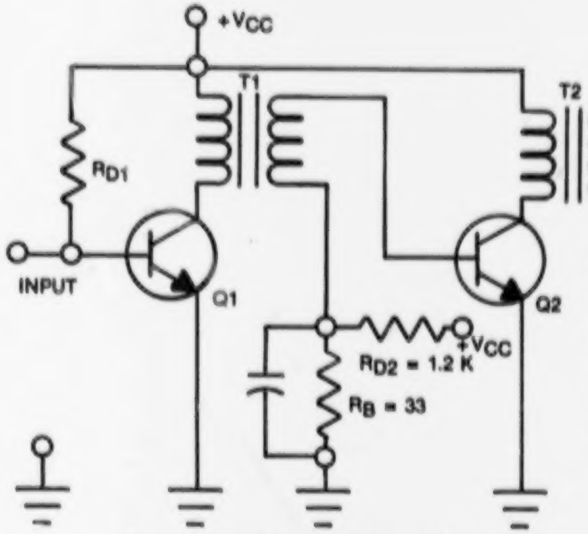

+VCC
L1
RD1
RD2
L2
INPUT
Q1
C1
Q2

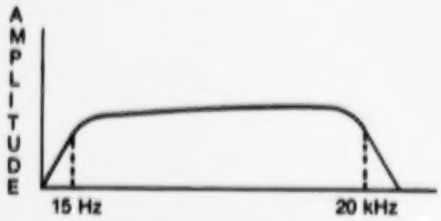
Impedance Coupling



Response Curve
(Impedance Coupling)

E. Transformer coupling transfers the signal through transformer action from one stage to the other and has advantages for use in impedance matching.


+VCC
T1
T2
LOAD
RD1
INPUT
Q1
Q2
+VCC
RD2 = 1.2 K
RB = 33



Transformer-Coupled Amplifier

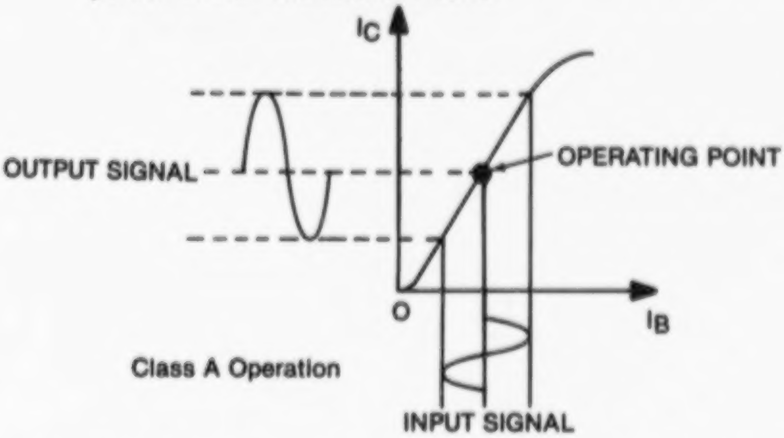
Frequency Response of Transformer-Coupled Audio Amplifier

INFORMATION SHEET

VII. **Classes of amplifier operation**

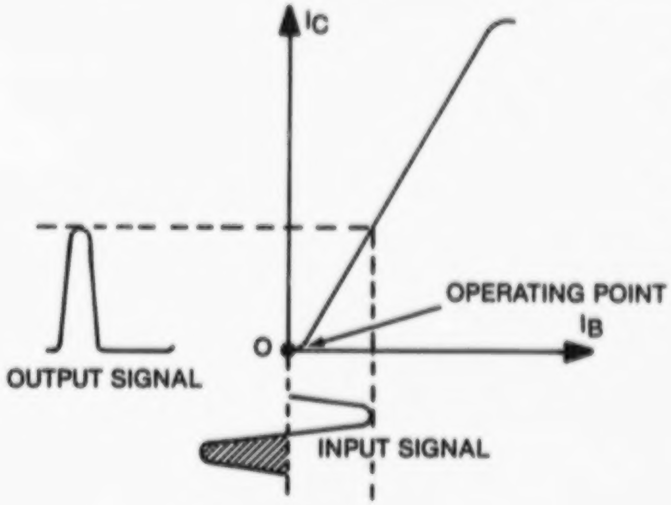
A. There are four basic classes of operation for amplifiers: class A, class AB, class B, and class C.

B. Class A amplifiers are biased to allow collector current to flow during 360 degrees of the input signal cycle and are designed to operate in the linear portion of their characteristic curve.


I_C
OUTPUT SIGNAL
OPERATING POINT
O
I_B
INPUT SIGNAL

Class A Operation

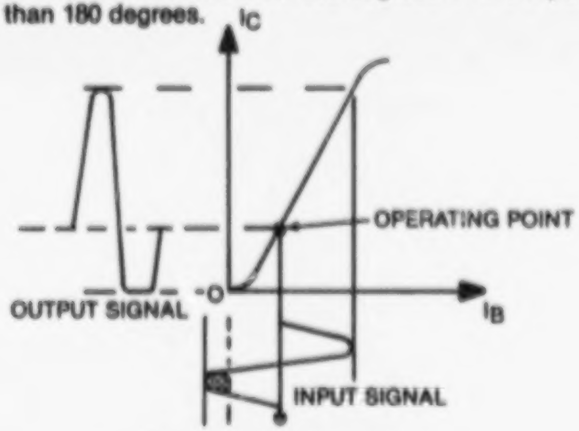
C. Class B amplifiers are biased to operate for 180 degrees of the input cycle.


I_C
OPERATING POINT
I_B
O
OUTPUT SIGNAL
INPUT SIGNAL

Class B Operation

INFORMATION SHEET

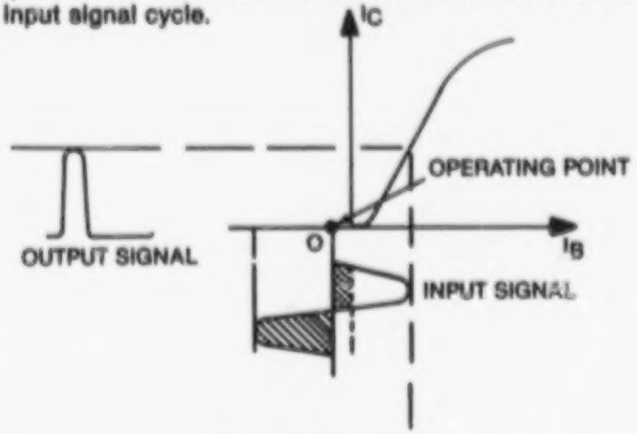
D. Class AB amplifiers are biased to operate between class A and class B, thus collector current flows for less than 360 degrees of the input signal cycle, but more than 180 degrees.



I_C
OPERATING POINT
OUTPUT SIGNAL
O
I_B
INPUT SIGNAL

Class AB Operation

E. Class C amplifiers are biased to allow collector current to flow less than half of the input signal cycle.



I_C
OPERATING POINT
OUTPUT SIGNAL
O
I_B
INPUT SIGNAL

Class C Operation

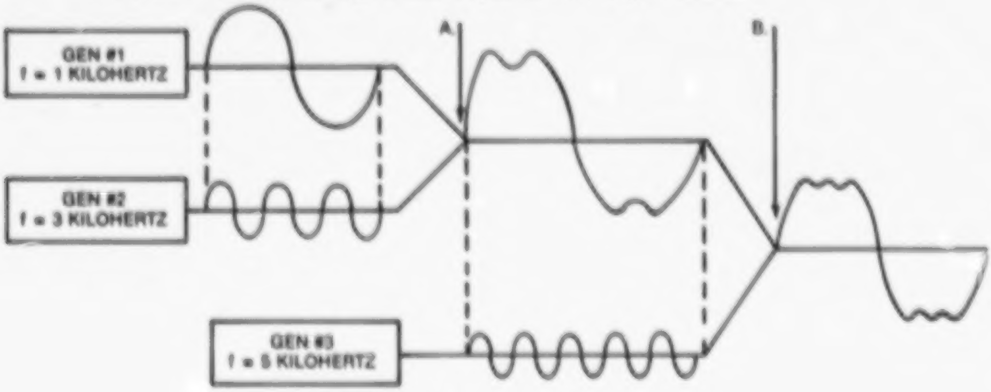
VIII. **Fundamentals of harmonic generation**

A. A sine wave is the only waveform that contains only one frequency with an amplitude that varies as a sine curve.

B. A nonsinusoidal waveform is one that does not vary as a sine curve.

INFORMATION SHEET

C. When an external source changes the shape of a sine wave (producing a nonsinusoidal waveform), other frequencies are generated.



Complex Wave Generation

D. A fundamental frequency is the lowest frequency component in a complex waveform.

E. A harmonic frequency is a multiple of the fundamental frequency.

(NOTE: The harmonic frequencies that are even multiples of the fundamental frequency are referred to as even harmonics; odd multiples are called odd harmonics.)

F. An amplifier operating in the nonlinear portion of its characteristic curve generates harmonic frequencies.

G. Class AB, B, and C amplifiers operate in the non-linear portion of their characteristic curve and generate harmonic frequencies.

1. Harmonics generated in class B operation are predominately even harmonics.

   (NOTE: Odd harmonics are also generated, but their amplitudes are small in comparison to the even harmonics.)

2. Both even and odd harmonics of large value are generated in class C operation.

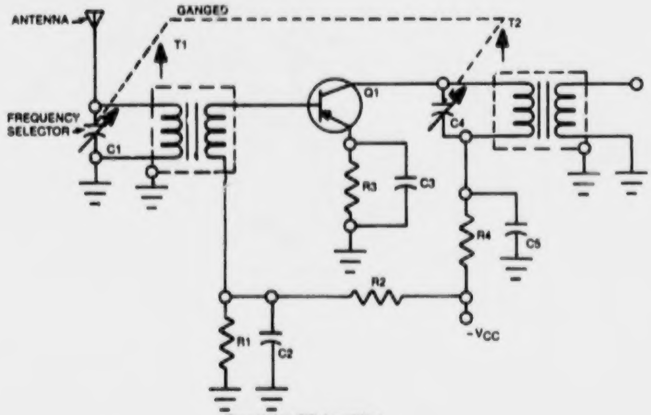
3. An overdriven amplifier generates odd harmonics.

IX. **Characteristics of narrow band amplifiers**

A. RF amplifiers are usually narrow band amplifiers tuned to a specific frequency, and are basically one of two types: the RF voltage, low-level, or small-signal amplifier; and the RF power amplifier.

INFORMATION SHEET

B. Low-level amplifiers usually employ various types of transistors or IC's as the active device and are operated class A.



Transistor RF Amplifier

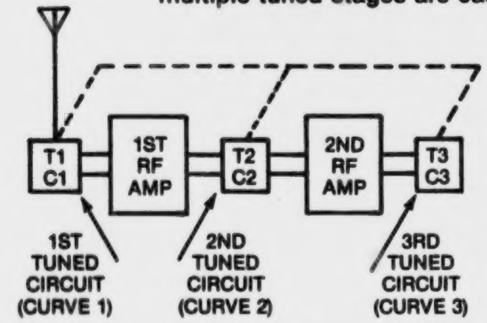
C. Narrow-band amplifiers commonly use tuned circuits to select the desired signal frequency and other components to provide for bias and DC stabilization.

1. The parallel, resonant "tank" circuit, consisting of transformer T1 and capacitor C1 selects the desired input signal from the antenna.
2. The collector tank circuit C4 and T2 develops the signal at the output of the stage.

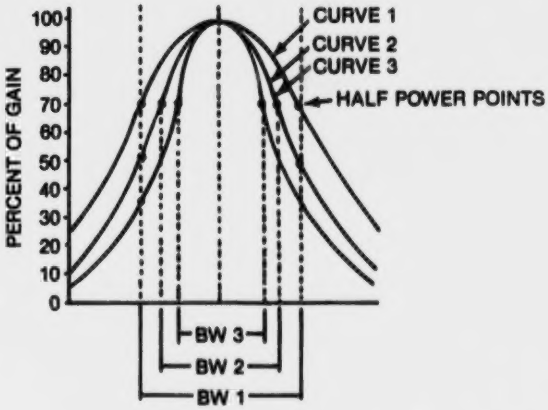
   (NOTE: The antenna and collector tank circuits are tuned to resonate at the same frequency.)
3. Capacitors C2 and C5 act as decoupling capacitors to isolate the RF signal from the power supply.
4. R4 is a voltage dropping resistor which provides the proper collector voltage.
5. The DC operating point of the transistor is established by the voltage divider R1 and R2.
6. Resistors R1 and R3 are stabilizing resistors.
7. Capacitor C3 prevents degeneration.

INFORMATION SHEET

D. A single amplifier seldom provides adequate amplification and, therefore, multiple tuned stages are cascaded with four major resultant effects:


T1
C1
1ST
RF
AMP
T2
C2
2ND
RF
AMP
T3
C3
1ST
TUNED
CIRCUIT
(CURVE 1)
2ND
TUNED
CIRCUIT
(CURVE 2)
3RD
TUNED
CIRCUIT
(CURVE 3)

Block Diagram of Cascaded RF Amplifiers



Response Curves for Cascaded Tuned Circuits

1. Decreased overall bandwidth

2. Increased selectivity

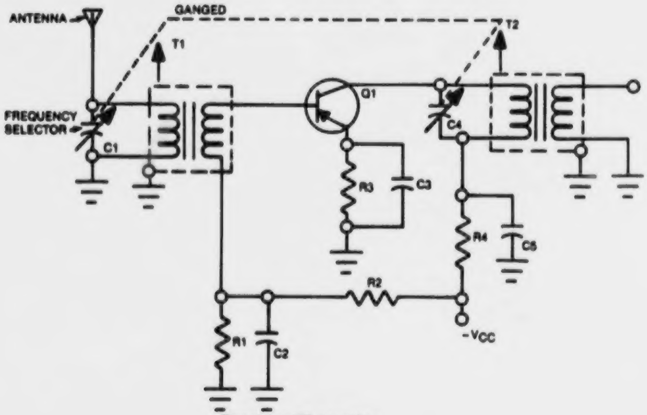
3. Increased amplification of the signal.

X. **Symptoms of component malfunctions in narrow band amplifiers**

A. Knowing component functions in relation to DC and signal sources is of primary importance in troubleshooting.

INFORMATION SHEET

B. The functions of the DC bias resistors, emitter swamping resistor, collector load resistor, and AC bypass capacitors in RF amplifier and audio amplifiers are the same.



Transistor RF Amplifier

C. If C1 were to open causing malfunction of the tuned circuit, total Q and selectivity of the stage would decrease resulting in symptoms of

1. Lower than normal output signal
2. Increased bandwidth
3. Decreased signal-to-noise ratio
4. Bias voltage normal
5. Collector voltage normal
6. Resonant frequency of input tank circuit higher than normal.

D. If the primary of T1 were to open, the signal would not be coupled across T1 causing

1. No output signal
2. Bias voltage normal
3. Collector voltage normal.

E. If C4 opens, the total circuit Q is decreased causing

1. Lower than normal output signal
2. Increased bandwidth

INFORMATION SHEET

3. Decreased signal-to-noise ratio

4. Higher than normal resonant frequency of output tank circuit.

F. If the primary of T2 opens, DC collector voltage is not available causing

1. Zero collector voltage

2. No amplification

3. No signal output.

G. If C1 or primary of T1 shorted, all incoming signals are shorted out with the major measurable symptoms being

1. No output signal

2. Bias and collector voltage normal.

H. If C4 or primary of T2 shorted, the output coupling would not exist resulting in measurable symptoms of

1. No output signal

2. Slight increase in collector voltage.

I. If the secondary of T1 shorted, coupling of signal to the transistor would not be accomplished causing

1. No output signal

2. Slight increase in forward bias

3. Slight decrease in collector voltage.

J. If the secondary of T2 shorted, the output signal is shorted out resulting in symptoms of

1. No output signal

2. Normal bias and collector voltages.

INFORMATION SHEET

XI. Feedback considerations in RF amplifiers

A. Feedback may be defined as the transferring of energy from a high-level (output) point back to a low-level (input) point in an amplification system.

B. There are two types of feedback: regenerative feedback and degenerative feedback.

   1. Regenerative feedback aids the input signal.

   2. Degenerative feedback opposes the input signal.

C. Regenerative feedback may be used when it is desirable to produce a higher gain. It

   1. Reduces bandwidth

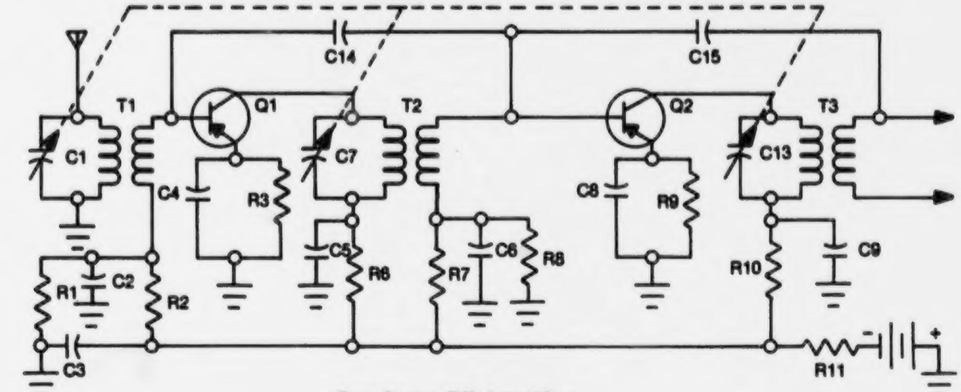
   2. Increases distortion

   3. Produces instability, resulting in a tendency to produce oscillations

   4. Is not generally desirable in Rf amplifiers.

D. Regenerative feedback may be neutralized by use of "neutralizing" capacitors to introduce an equal amount of degenerative feedback.

   (NOTE: C-14 and C-15 in the diagram below are neutralizing capacitors.)



Two-Stage RF Amplifier

E. Degenerative feedback may also be introduced by using an unbypassed emitter resistor. It

   1. Widens bandwidth

   2. Decreases distortion

   3. Reduces the tendency of an amplifier to oscillate

INFORMATION SHEET

XII. General characteristics of wide band amplifiers

A. A wide-band amplifier has the ability to amplify nonsinusoidal signals.

(NOTE: Video amplifiers are wide-band amplifiers.)

B. A nonsinusoidal waveform contains a fundamental frequency and numerous harmonic frequencies, all of which may be amplified equally in a properly designed wide-band amplifier.

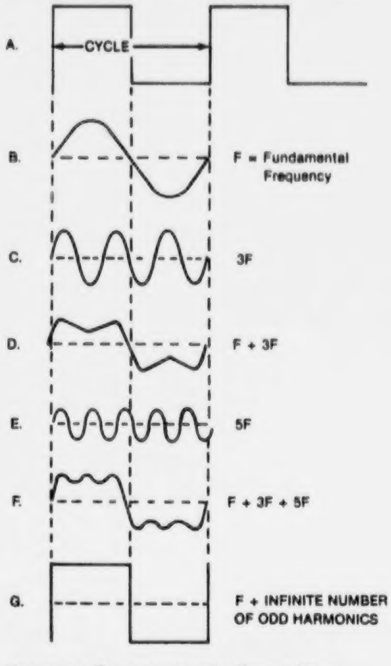
C. Coupling capacitors tend to distort low frequencies, and distributed capacitance tends to distort high frequencies.

XIII. Characteristics of nonsinusoidal waveforms

A. A square wave is a typical example of a nonsinusoidal waveform.

B. A square is composed of a fundamental frequency and an infinite number of odd harmonics which have specific phase and amplitude relationships.

1. The flat tops and bottoms of a square wave represent the low-frequency components.
2. The steeply sloped sides of a square wave represent the high-frequency component.
3. When the fundamental frequency goes through zero in a positive direction, all harmonics go through zero in a positive direction.
4. Amplitudes of the harmonics have a definite relationship to the fundamental, i.e., the amplitude of the third harmonic is one-third the fundamental, the fifth harmonic is one-fifth the amplitude of the fundamental, etc.


A.
CYCLE
B.
F = Fundamental Frequency
C.
3F
D.
F + 3F
E.
5F
F.
F + 3F + 5F
G.
F + INFINITE NUMBER OF ODD HARMONICS

Frequency Components of a Square Wave

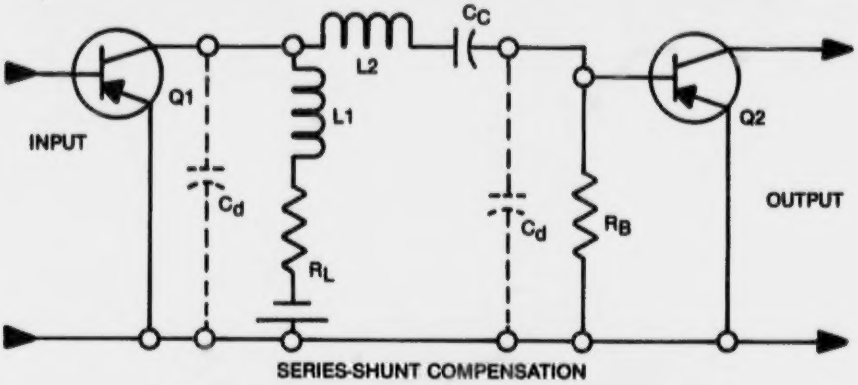
XIV. Methods of improving frequency response for broad-band amplifier circuits

A. The high-frequency limitations imposed by distributed capacitance may be compensated for by introducing circuit components to increase the response characteristics.

INFORMATION SHEET

B. Using a relatively small load resistor, the bandwidth of a circuit is increased. This also decreases gain.

C. Shunt compensation may be employed by the addition of a shunt peaking coil (L1) in series with the load resistor thus increasing the impedance at high frequencies which, in turn, produces an improved high frequency response.



Wide-Band Amplifier High Frequency Compensation

(NOTE: L1 forms a parallel resonant circuit with the distributed capacitance. The component values are selected so that the impedance of the resonant circuit increases at high frequencies improving the circuit responses.)

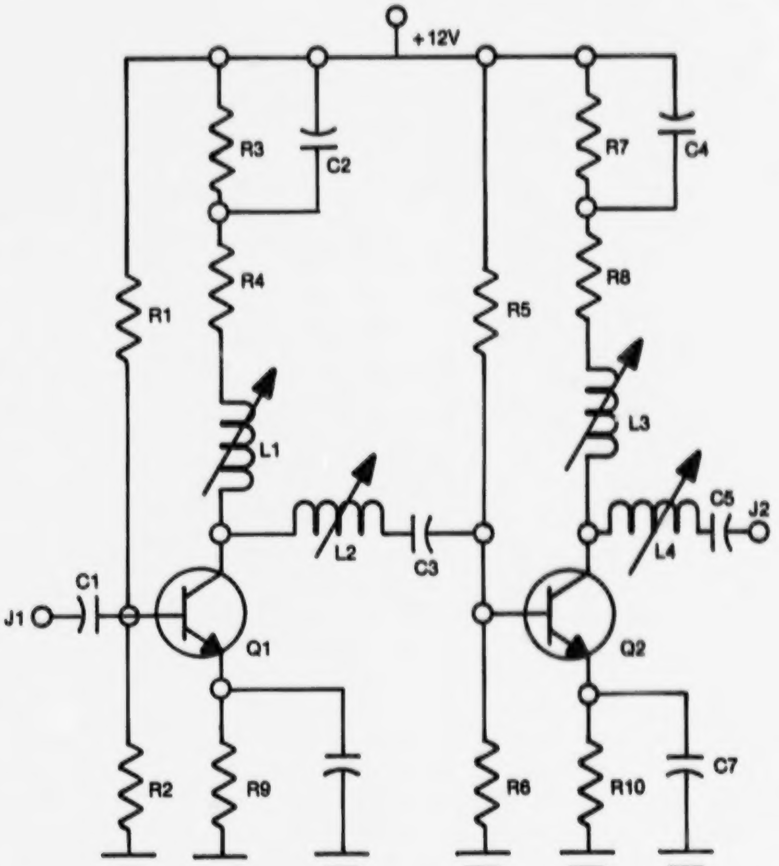
D. Series compensation may be employed for improved high frequency response by adding a series peaking coil (L2) forming a series resonant circuit with the distributed capacitance at the input to the second stage.

(NOTE: The characteristic of the series resonant circuit is such that at the resonant frequency, maximum voltage is developed across the capacitor [in this case, the distributed capacitance] which provides maximum voltage to the input of the transistor.)

E. Low-frequency response is limited by the coupling capacitor and the input impedance to the transistor and may be minimized by proper selection of component values.

INFORMATION SHEET

F. Phase distortion and loss of gain at low frequencies may be minimized by adding a low-frequency, compensation network in series with the load resistor.


+12V
R1
R2
R3
C2
R4
L1
L2
C3
R5
R6
R7
C4
R8
L3
L4
C5
J2
J1
C1
Q1
Q2
R9
R10
C7

Compensated Wideband Amplifier

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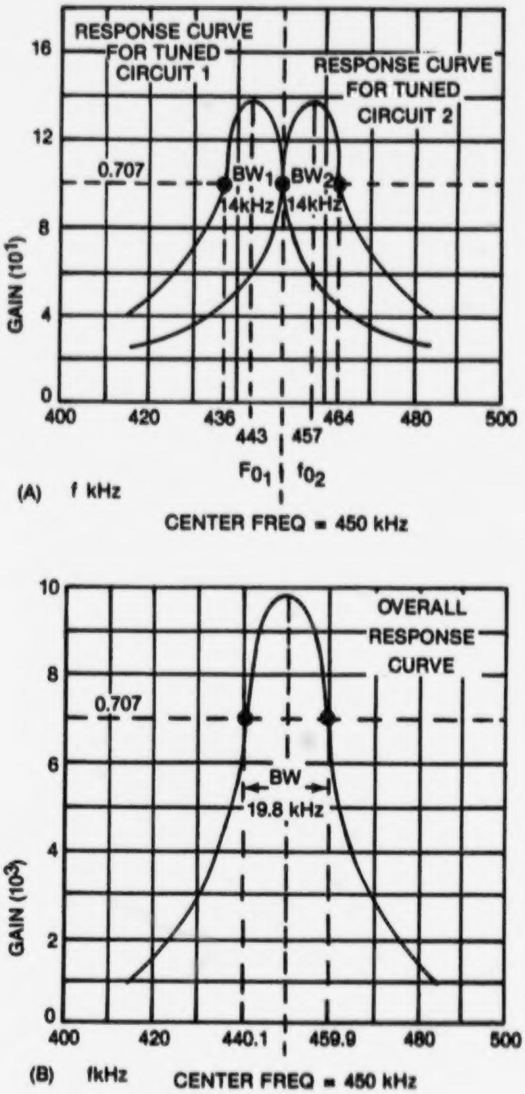
G. Stagger tuning of multistage amplifier systems may be employed to broaden the bandwidth.

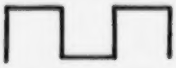
(NOTE: The tuned circuit of one stage is tuned slightly below the center frequency, the other slightly above, resulting in an overall response of the amplifiers that is greater than either of the single stages.)

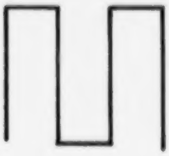


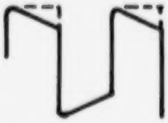
Response Curves

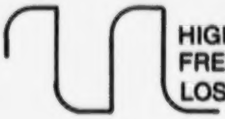
INFORMATION SHEET

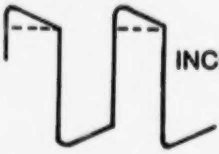
H. With a square wave input, the frequency response characteristics may be estimated by viewing the waveform at the output of the amplifier.

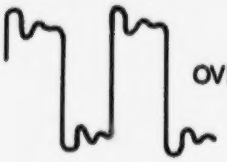

INPUT


NORMAL OUTPUT

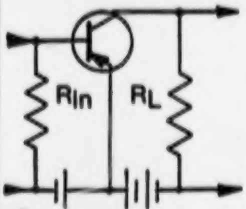
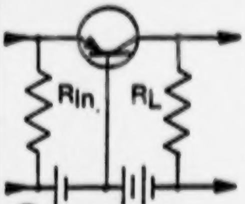
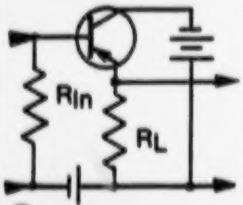

LOW FREQUENCY LOSS


HIGH FREQUENCY LOSS

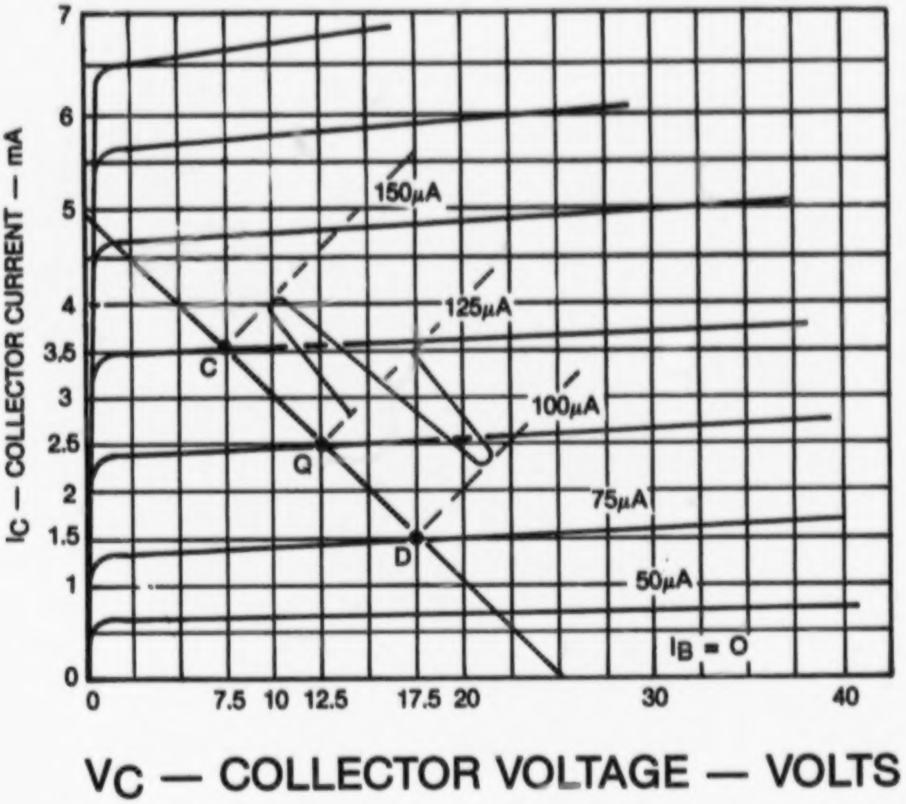

INCREASED GAIN

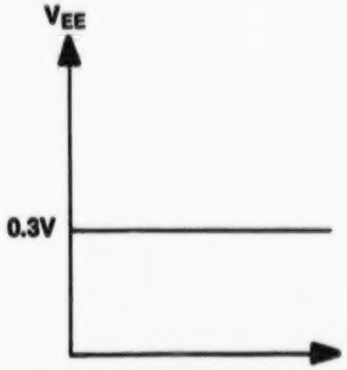

OVER-COMPENSATION

Comparison of Transistor Circuit Combinations

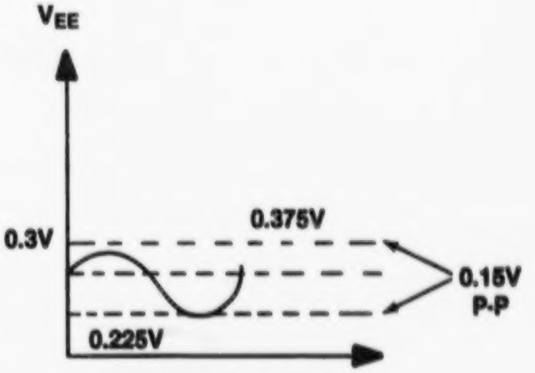
Character-istics	 Common Emitter	 Common Base	 Common Collector
Voltage Gain $A_e = \frac{E\ out}{E\ in}$	High (300)	High (500)	Low Less Than One
Current Gain $A_I = \frac{I\ out}{I\ in}$	High (50)	Low (0.97)	High (50)
Power Gain $A_P = \frac{P\ out}{P\ in}$	Very High (12,000)	Medium (400)	Low (30)
Input Impedance	Medium (1,000)	Low (60)	High (400,000)
Output Impedance	Medium (50,000)	High (1 M)	Low (100)
Phase Reversal	Yes	No	No

Load-Line for C-E Amplifier



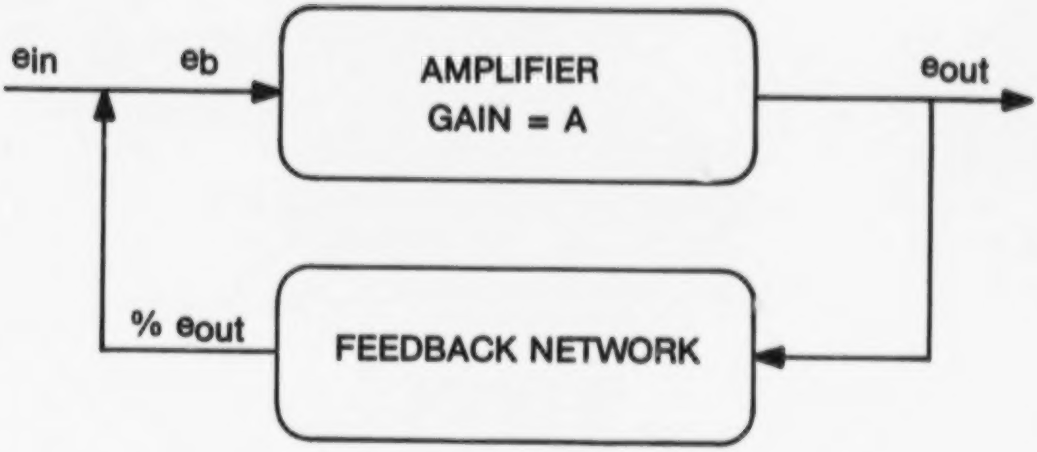


Static Operation Point Q


V_{EE}
0.3V
0.375V
0.225V
0.15V
P-P

Resulting Base-Emitter Voltage

Feedback


e_{in}
e_b
AMPLIFIER
GAIN = A
e_{out}
% e_{out}
FEEDBACK NETWORK

$$e_{in} + \% \, e_{out} = e_b$$

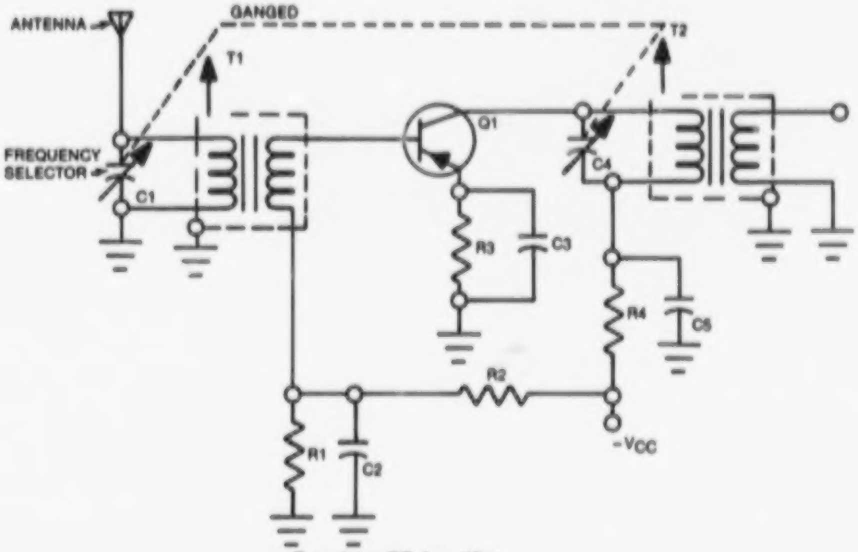
$$A_{FB} = \frac{e_{out}}{e_{in}} = \frac{A}{1 \pm \%} \quad e_{out} \quad A$$

AMPLIFIERS
UNIT III

ASSIGNMENT SHEET #1 — IDENTIFY COMPONENT FUNCTIONS AND MALFUNCTIONS IN AN AMPLIFIER CIRCUIT

NAME ______________________________ SCORE ______________

Directions: Answer the following questions related to the diagram below.


ANTENNA
GANGED
T1
T2
Q1
FREQUENCY SELECTOR
C1
C4
R3
C3
R4
C5
R2
-VCC
R1
C2

Transistor RF Amplifier

1. What components make up the input tank circuit?

2. What is the function of the input tank circuit?

3. What components make up the output tank circuit?

ASSIGNMENT SHEET #1

4. What is the function of the output tank circuit?

5. What is the purpose of C2 and C5?

6. What is the purpose of R4?

7. What is the purpose of R1 and R2?

8. R1 in combination with R3 provide for what?

9. If R4 were to open, what would the effect be on the DC collector voltage of Q1?

10. What would be the effect on the DC collector voltage of Q1 if the primary of T2 were to open?

11. What would happen to the output signal if C2 would become shorted?

12. What would be the effect on the DC collector voltage of Q1 if R3 opened?

AMPLIFIERS
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. T1 and C1
2. The function of the input tank circuit is to select the desired input signal from the antenna.
3. T2 and C4
4. The function of the output tank circuit is to develop the output signal of the stage.
5. C2 and C5 are decoupling capacitors.
6. R4 is a voltage dropping resistor used to provide proper collector voltage for operation.
7. R1 and R2 make up a voltage divider to establish bias voltages.
8. R1 in combination with R3 provides for DC stabilization of the amplifier circuit.
9. Reduced to zero.
10. Collector voltage would be reduced to zero.
11. No output signal.
12. Collector voltage would equal, or nearly equal, $-V_{CC}$.

AMPLIFIERS
UNIT III

JOB SHEET #1 — CONSTRUCT AND ANALYZE AN AUDIO IC AMPLIFIER CIRCUIT

A. Equipment and materials needed

1. 2-watt audio amplifier IC; LM 380 or equivalent
2. 2.2 microfarad electrolytic capacitor (2)
3. 470 microfarad electrolytic capacitor (2)
4. 0.1 microfarad ceramic capacitor
5. 47 Kilohm, 1/4 watt resistor
6. 2.7 ohm, 1/4 watt resistor
7. 8-ohm speaker
8. Audio signal generator
9. DC power supply
10. Oscilloscope
11. Specification sheet for audio amplifier IC (LM380 or equivalent)

B. Procedure

1. Using the specification sheet for the IC, find and record the following?

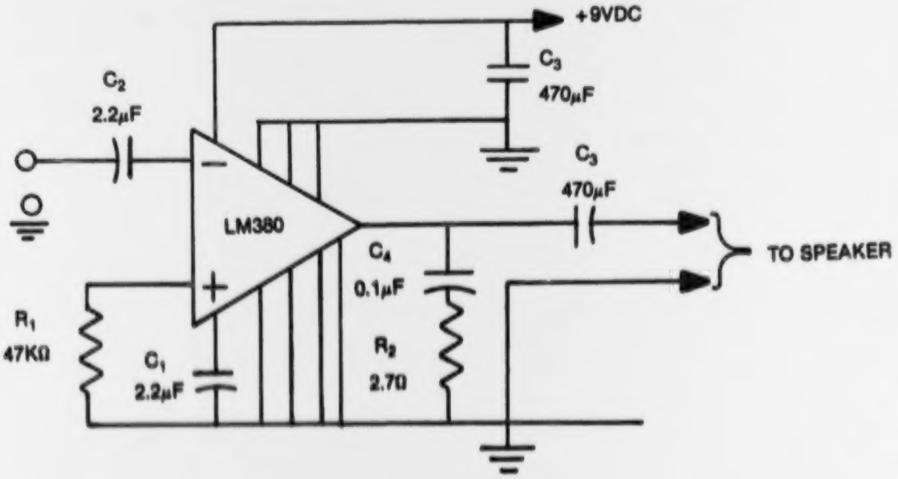
   Max. source voltage ____________ volts

   Power dissipation ____________ watts

   Maximum output signal ____________ watts

JOB SHEET #1

2. Construct the audio amplifier circuit according to the following schematic.



3. Ground the input terminal.

4. Is there any sound coming from the speaker?

   Check one ____________ yes ____________ no

   (NOTE: Ideally no sound should be produced by the speaker with no input. If sound is produced, the sound is being produced within the circuit either through unwanted oscillation or by imperfections in the IC or circuit components.)

5. Apply a 1 KHz signal from the audio generator to the input terminal of the IC.

6. Connect an oscilloscope across the output to the speaker.

7. Gradually increase the input amplitude from the signal generator until signal distortion begins to appear at the output.

8. Measure the input amplitude with your oscilloscope and record its peak-to-peak amplitude.

   Maximum input amplitude ____________ volts p-p

9. Measure the output amplitude with your oscilloscope and record the peak-to-peak amplitude.

   Maximum undistorted output ____________ volts p-p

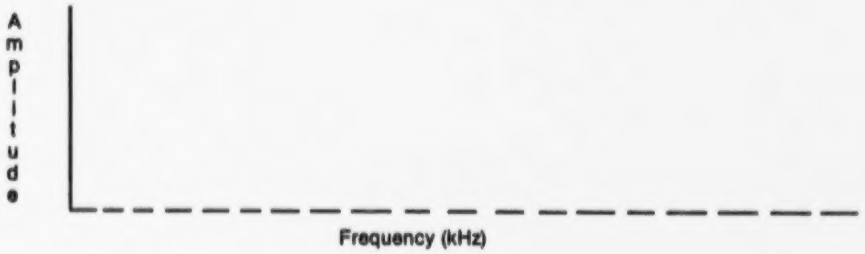
10. Reduce the input to approximately 75% of its maximum input amplitude determined in step 8.

JOB SHEET #1

11. Reduce the output frequency of the signal generator to zero hertz.

12. From the specification sheet for the IC, determine the frequency limits of the IC.

13. While observing the output signal with the oscilloscope, increase the frequency of the input from the audio generator in increments to determine the frequency response characteristics of the circuit. Construct a frequency vs. amplitude graph below.



14. What is the frequency response of the circuit?

Frequency response = ____________ to ____________

15. Compare the frequency response of the circuit to the frequency limits of the IC as determined from the specification sheet.

16. Turn off all power to test equipment.

17. Return test equipment and materials to their proper storage location.

AMPLIFIERS
UNIT III

JOB SHEET #1 PRACTICAL TEST — CONSTRUCT AND ANALYZE AN AUDIO IC AMPLIFIER

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Determined specification from specification sheet.	______	______
3. Properly constructed circuit from schematic.	______	______
4. Properly completed procedure to determine maximum undistorted output.	______	______
5. Properly completed procedure to obtain frequency response of the circuit.	______	______
6. Properly compared specified frequency limits of the IC to the frequency response of the circuit.	______	______
7. Turned off all power to test instruments.	______	______
8. Checked in/put away equipment and materials.	______	______
9. Cleaned the work area.	______	______
10. Used proper equipment correctly.	______	______
11. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Circuit construction	Correct			Incorrect
	4	3	2	1
Use of specification sheet	Proper			Improper
	4	3	2	1
Maximum undistorted output	Determined			Not determined
	4	3	2	1
Frequency response graph construction	Correct			Incorrect
	4	3	2	1
Frequency response comparison	Appropriate			Not appropriate

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

AMPLIFIERS
UNIT III

NAME ______________________________ SCORE _______________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. The varying electrical voltage or current that carries desirable intelligence

_____b. The process of returning part of the output of an amplifier back to the input in such a way that it tends to cancel or reduce the input

_____c. The process of returning part of the output of an amplifier back to the input in such a way that it tends to aid the input

_____d. The process used to obtain degeneration or regeneration

_____e. Preventing transfer or feedback of energy from one circuit to another

_____f. The amount by which a signal is increased or amplified

_____g. The process of nullifying the reactive feedback to prevent unwanted oscillations in an amplifier

_____h. An amplifier circuit used between two stages to reduce the loading effects of one stage on the other

1. Neutralization
2. Decoupling
3. Feedback
4. Buffer
5. Regeneration
6. Degeneration
7. Gain
8. Signal

2. Complete the following statements concerning basic amplifier principles by inserting the word(s) that best completes each statement.

a. Amplifiers are generally classified as ______________ and ______________ amplifiers.

b. When it is necessary to increase signal voltage only, the stage is classified as a ______________ amplifier.

c. Amplification is dependent on the ability of an input signal to cause a change in the ______________ of the active device such as a transistor.

d. ______________ of an amplifier is the ratio of the output to the input.

TEST

3. Match the transistor amplifier configurations on the right with their correct list of characteristics.

______a.	1) Relatively high voltage gain	1. Common-collector
	2) High current gain	2. Common-emitter
	3) High power gain	3. Common-base
	4) Medium input impedance	
	5) Medium output impedance	
	6) Phase reversal between input and output	
______b.	1) Relatively high voltage gain	
	2) Low current gain (less than 1.0)	
	3) Medium power gain	
	4) Low input impedance	
	5) High output impedance	
	6) Input and output signals in-phase	
______c.	1) Low voltage gain	
	2) High current gain	
	3) Low power gain	
	4) High input impedance	
	5) Low output impedance	
	6) No phase reversal from input to output	

4. Select true statements related to stabilization of transistor amplifiers by placing an "X" in the blanks preceding the statements.

______a. The effects of emitter-base junction resistance changes may be reduced by installing a resistor in series with the emitter.

______b. The emitter resistor is often called a swamping resistor because it swamps out the effects of changes in the emitter-base junction resistance.

______c. The resistor in the emitter circuit introduces regeneration of the AC signal.

TEST

_____d. An emitter bypass capacitor is added in parallel to the swamping resistor to enable the AC signal to "see" ground on the emitter thus allowing for temperature stability without degeneration of the signal.

_____e. A self-bias arrangement (or collector feedback) reduces thermal stability by providing a form of regenerative feedback from the collector.

_____f. Thermistor stabilization is accomplished by inserting a thermistor in the biasing network to counteract the variations caused by changes in temperature.

5. Complete the following statements related to types of distortion by inserting the word(s) that best completes each statement.

   a. ____________, in general terms, is when the waveshape of the output signal varies in any form with respect to the waveshape of the input signal.

   b. Amplifiers are subject to four basic forms of distortion: ____________, ____________, ____________, and ____________.

   c. ____________ distortion (also known as harmonic distortion) is the result of changing a waveshape so that its amplitude is not proportional to the amplitude of the original waveform.

   d. ____________ distortion occurs when not all frequencies are amplified equally by the amplifier.

   e. ____________ distortion, usually caused by reactive components in a circuit, occurs when some frequencies are delayed from input to output resulting in differing amounts of phase-shift for different frequencies.

   f. ____________ distortion occurs when two signals with different frequencies are intermixed, resulting in the production of sum and difference frequencies.

6. List four methods of coupling.

   a. ____

   b. ____

   c. ____

   d. ____

TEST

7. Select true statements concerning the classes of amplifier operation by placing an "X" in the blanks preceding the true statements.

_____a. There are four basic classes of operation for amplifiers: class A, class B, class C, and class D.

_____b. Class A amplifiers are biased to allow collector current to flow during 360 degrees of the input signal cycle and are designed to operate in the linear portion of their characteristic curve.

_____c. Class B amplifiers are biased to operate for 180 degrees of the input signal cycle.

_____d. Class C amplifiers are biased to operate between class A and class B, thus collector current flows for less than 360 degrees of the input signal cycle but more than 180 degrees.

_____e. Class D amplifiers are biased to allow collector current to flow less than half of the input signal cycle.

8. Complete the following statements concerning the fundamentals of harmonic generation by inserting the word(s) that best completes each statement.

a. A ____________ wave is the only waveform that contains only one frequency with an amplitude that varies as a sine curve.

b. When an external source changes the shape of a sine wave (producing a non-sinusoidal waveform), other ____________ are generated.

c. A fundamental frequency is the ____________ frequency component in a complex waveform.

d. A ____________ frequency is a multiple of the fundamental frequency.

e. Harmonics generated in class B operation are predominately ____________ harmonics.

f. Both ____________ and ____________ harmonics of large value are generated in class C operation.

g. An overdriven amplifier generates ____________ harmonics.

9. Complete the following statements concerning the characteristics of narrow-band amplifiers by inserting the word(s) that best completes each statement.

a. RF amplifiers are usually narrow band amplifiers tuned to a specific ____________, and are basically one of two types: the RF voltage, low-level, or small-signal amplifier; and the RF power amplifier.

b. Low-level amplifiers usually employ various types of transistors or IC's as the active device and are operated class ____________.

TEST

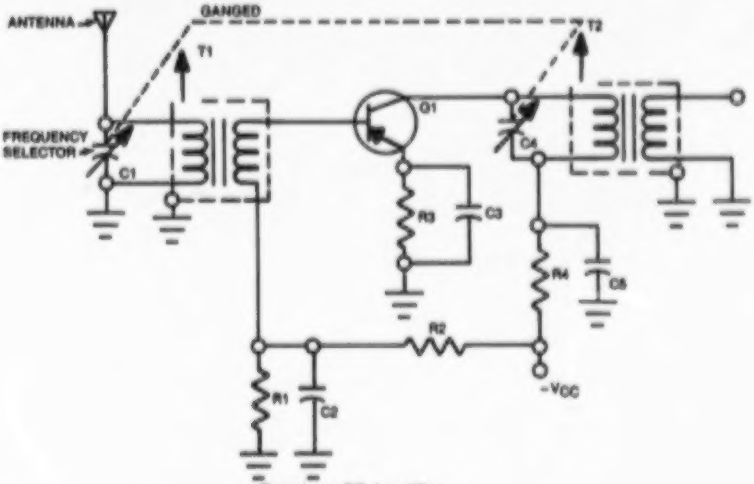
c. A single amplifier seldom provides adequate amplification and, therefore, multiple tuned stages are cascaded with four major resultant effects:

1) ____________________

2) ____________________

3) ____________________

10. Match component malfunctions on the right with the list of resultant symptoms. (Refer to diagram below for parts identification.)



Transistor RF Amplifier

_____ a. Resultant symptoms of __________

1) Lower than normal output signal
2) Increased bandwidth
3) Decreased signal-to-noise ratio
4) Bias voltage normal
5) Collector voltage normal
6) Resonant frequency of input tank circuit higher than normal

_____ b. Resultant symptoms of __________

1) No output signal
2) Bias voltage normal
3) Collector voltage normal

1. Primary T1 open
2. C1 open
3. Primary T2 open
4. C4 open
5. C1 or primary of T1 shorted
6. Secondary of T1 shorted
7. C4 or primary or T2 shorted
8. Secondary of T2 shorted

TEST

_____c. Resultant symptoms of ____________

1) Lower than normal output signal
2) Increased bandwidth
3) Decreased signal-to-noise ratio
4) Higher than normal resonant frequency of output tank circuit

_____d. Resultant symptoms of ____________

1) Zero collector voltage
2) No amplification
3) No signal output

_____e. Resultant symptoms of ____________

1) No output signal
2) Bias and collector voltage normal

_____f. Resultant symptoms of ____________

1) No output signal
2) Slight increase in collector voltage

_____g. Resultant symptoms of ____________

1) No output signal
2) Slight increase in forward bias
3) Slight decrease in collector voltage

_____h. Resultant symptoms of ____________

1) No output signal
2) Normal bias and collector voltages

TEST

11. Complete the following statements concerning feedback considerations in RF amplifiers by inserting the word(s) that best completes each statement.

    a. ____________ may be defined as the transferring of energy from a high-level (output) point back to a low-level (input) point in an amplification system.

    b. Regenerative feedback ____________ the input signal.

    c. Degenerative feedback ____________ the input signal.

    d. Regenerative feedback produces instability resulting in a tendency to produce ____________.

    e. Regenerative feedback may be neutralized by use of "neutralizing" capacitors to introduce an equal amount of ____________ feedback.

12. Complete the following statements concerning the general characteristics of wide band amplifiers by inserting the word(s) that best completes each statement.

    a. A wide-band amplifier has the ability to amplify ____________ signals.

    b. A ____________ waveform contains a fundamental frequency and numerous harmonic frequencies, all of which may be amplified equally in a properly designed wide-band amplifier.

    c. Coupling capacitors tend to distort ____________ frequencies and distributed capacitance tends to distort ____________ frequencies.

13. Select true statements concerning the characteristics of nonsinusoidal waveforms by placing an "X" in the blanks preceding the true statements.

    _____a. A square wave is a typical example of a nonsinusoidal waveform.

    _____b. A square wave is composed of a fundamental frequency and an infinite number of even harmonics which have specific phase and amplitude relationships.

    _____c. The flat tops and bottoms of a square wave represent the high-frequency components.

    _____d. The steeply sloped sides of a square wave represent the low-frequency component.

    _____e. When the fundamental frequency goes through zero in a positive direction, all harmonics go through zero in a positive direction.

    _____f. Amplitudes of the harmonics have a definite relationship to the fundamental, i.e., the amplitude of the third harmonic is one-third the fundamental, the fifth harmonic is one-fifth the amplitude of the fundamental, etc.

TEST

14. Complete the following statements concerning the methods of improving frequency response for broadband amplifier circuits by inserting the word(s) that best completes each statement.

    a. The use of a relatively small load resistor will ____________ the bandwidth of an amplifier circuit. (This also decreases gain.)

    b. Shunt compensation may be employed by the addition of a shunt ____________ coil (L1) in series with the load resistor, thus increasing the impedance at high frequencies which, in turn, produces an improved high-frequency response.

    c. Series compensation may be employed for improved high frequency response by adding a series ____________ coil forming a series resonant circuit with the distributed capacitance at the input to the second stage.

    d. Low-frequency response is limited by the ____________ capacitor and the input impedance to the transistor and may be minimized by proper selection of component values.

    e. Phase distortion and loss of gain at ____________ frequencies may be minimized by adding a low-frequency compensation network in series with the load resistor.

    f. Stagger tuning of multistage amplifier systems may be employed to broaden the ____________.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

15. Identify component functions and malfunctions in an amplifier circuit. (Assignment Sheet #1)

16. Demonstrate the ability to construct and analyze an audio IC amplifier circuit. (Job Sheet #1)

AMPLIFIERS
UNIT III

ANSWERS TO TEST

1. a. 8
   b. 6
   c. 5
   d. 3
   e. 2
   f. 7
   g. 1
   h. 4

2. a. Power, voltage
   b. Voltage
   c. Resistance
   d. Gain

3. a. 2
   b. 3
   c. 1

4. a, b, d

5. a. Distortion
   b. Amplitude, frequency, phase, intermodulation
   c. Amplitude
   d. Frequency
   e. Phase
   f. Intermodulation

6. a. Direct
   b. Resistance-capacitance (RC)
   c. Impedance (LC)
   d. Transformer

7. b, c

8. a. Sine
   b. Frequencies
   c. Lowest
   d. Harmonic
   e. Even
   f. Even, odd
   g. Odd

ANSWERS TO TEST

9. a. Frequency
   b. A
   c. 1) Decreased overall bandwidth
      2) Increased selectivity
      3) Increased amplification of the signal

10. a. 2 (C1 open)
    b. 1 (Primary T1 open)
    c. 4 (C4 open)
    d. 3 (Primary T2 open)
    e. 5 (C1 or primary of T1 shorted)
    f. 7 (C4 or primary t2 shorted)
    g. 6 (Secondary of T1 shorted)
    h. 8 (Secondary of T2 shorted)

11. a. Feedback
    b. Aids
    c. Opposes
    d. Oscillations
    e. Degenerative

12. a. Nonsinusoidal
    b. Nonsinusoidal
    c. Low, high

13. a, e, f

14. a. Increase
    b. Peaking
    c. Peaking
    d. Coupling
    e. Low
    f. Bandwidth

15. Evaluated to the satisfaction of the instructor

16. Performance skills evaluated according to industry standards and to the satisfaction of the instructor

INTEGRATED CIRCUITS
UNIT IV

UNIT OBJECTIVE

After completion of this unit, the student should be able to select, replace, and properly handle integrated circuits. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to integrated circuits with their correct definitions.
2. Select true statements concerning basic input parameters of the operational amplifier.
3. Complete statements concerning the output parameters of the operational amplifier.
4. Complete statements concerning the dynamic parameters of the operational amplifier.
5. List five advantages of active filters.
6. List two disadvantages of active filters.
7. Match types of active filters with their schematic diagrams.
8. Complete statements concerning Norton amplifier characteristics and circuits.
9. Complete statements concerning the operational characteristics of switching regulator circuits.
10. Complete statements concerning the characteristics of phase-locked-loops.

OBJECTIVE SHEET

11. Complete statements concerning timer circuit configurations using the 555 timer IC.

12. Select true statements concerning circuits used in conversion between analog and digital technologies.

13. Demonstrate the ability to:

    a. Construct a noninverting Norton amplifier and determine phase relationships and gain. (Job Sheet #1)

    b. Construct an inverting Norton amplifier and determine phase relationships and gain. (Job Sheet #2)

INTEGRATED CIRCUITS
UNIT IV

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Provide students with objective sheet.

C. Discuss unit and specific objectives.

D. Provide students with information sheet.

E. Discuss information sheet.

F. Provide students with job sheets.

G. Discuss and demonstrate the procedures outlined in the job sheets.

H. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate uses for manufacturer technical data sheets for selected devices.
2. List distributors in your area where integrated circuit devices may be purchased.
3. Select integrated circuits for use in specific applications by using the technical data sheets.
4. Visit manufacturers of integrated circuits.
5. Demonstrate proper handling procedures for integrated circuits.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

I. Administer test.

J. Evaluate test.

K. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Burr-Brown. *Integrated Circuits Data Book.* Tucson, Arizona: Burr-Brown Corporation, 1986.

B. Dugan, Frank R. *Linear Integrated Circuits for Technicians.* North Scituate, MA: Breton Publishers/Wadsworth Inc., 1984.

C. Floyd, Thomas L. *Electronic Devices.* Columbus, OH: Bell and Howell Co., 1984.

D. Millman and Grabel. *Microelectronics.* Second Edition. New York: McGraw-Hill Book Company, 1987.

E. Schrader, Robert L. *Electronic Communication.* Fifth Edition. New York: McGraw-Hill Book Company, 1985.

INTEGRATED CIRCUITS
UNIT IV

INFORMATION SHEET

I. **Terms and definitions**

A. Active filter — Filter that contains an active component such as an operational amplifier that introduces some signal gain

B. Common-mode signals — Voltages of equal amplitude and frequency, in-phase, and applied to both inputs of a differential amplifier

C. Differential amplifier — An amplifier that has two inputs and amplifies the difference between inputs to produce an output

D. Integrated circuit — A complete circuit consisting of a number of separate component parts manufactured as a single microchip package

E. Inverting amplifier — An amplifier that has an output signal 180 degrees out of phase with the input signal

F. Norton amplifier — A current driven operational amplifier circuit that amplifies AC signals

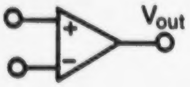
G. Operational amplifier (op amp) — An amplifier that exhibits a very high gain, high-input and low-output impedance, has a good rejection of common-mode signals, and has differential inputs

H. Phase-locked-loop — A closed-loop electronic circuit that contains a phase detector, low-pass filter, DC amplifier, and a voltage-controlled oscillator in a feedback loop

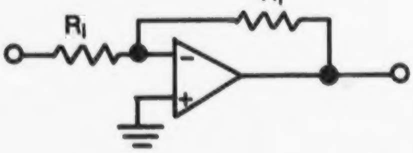
I. Summing amplifier — An amplifier circuit with an output that is the sum of individual voltages applied through a resistive network to the (−) input of an op amp

II. **Basic input parameters of the operational amplifier (op amp)**

A. The symbol for an operational amplifier (op amp) is a triangle with two input terminals.

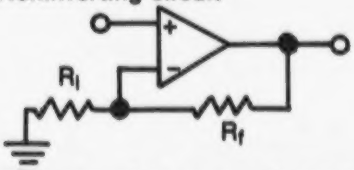


1. Inverting circuit

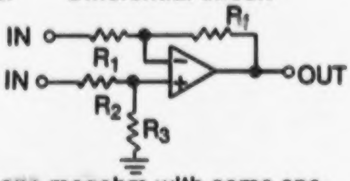


INFORMATION SHEET

2. Noninverting circuit



3. Differential circuit



B. Input resistance of an op amp is greater than one megohm with some special purpose op amps as high as 100 megohms.

C. Input capacitance is typically less than 2 pF.

(NOTE: This is an important factor when operating the op amp at high frequencies.)

D. Input bias current is the average of the two input currents, typically in the microampere range, and is held low by the high input resistance.

E. Input offset current is the difference of the two input bias currents when the output voltage is zero (typically may vary from a very small current up to as high as 20 mA).

F. Input offset voltage is the voltage that is applied to one of the input terminals to give a zero voltage output.

G. Input voltage range is the range of voltage common to both inputs and ground (common-mode input voltage).

H. Drift is the change in offset current and offset voltage caused by temperature changes.

I. Input differential range is the maximum difference signal that may be applied safely to the op amp input terminals.

III. **Output parameters of the operational amplifier**

A. Output resistance is the resistance looking into to output terminal and is typically a low value, varying from a few ohms to a few thousand ohms.

(NOTE: High input resistance and low output resistance make an op amp a good impedance matching device.)

B. Output short-circuit current is the maximum output current that the op amp can deliver to the circuit load.

C. Output voltage swing is the maximum peak voltage that the op amp can supply without saturation or clipping.

(NOTE: The voltage swing may be affected by the amount of load resistance.)

INFORMATION SHEET

IV. Dynamic parameters of the operational amplifier

A. The open-loop voltage gain is the ratio of the output voltage to the input voltage without external feedback and at a frequency of zero hertz.

B. Large-signal voltage gain is the ratio of the maximum voltage swing to the change in the input voltage required to drive the output from zero to a specified voltage.

C. The slew rate is the time rate of change of the output voltage at unity gain (gain of one).

(NOTE: Time rate of change indicates speed of change.)

D. The gain-bandwidth product is equal to the unity gain frequency and indicates the upper useful frequency of the circuit and gives a means of determining the bandwidth for any given gain.

E. Common-mode rejection ratio (CMRR) is the ratio of the common-mode input voltage to the generated output voltage and is a measure of the ability of the op amp to reject common-mode signals while amplifying differential signals. Expressed as a formula, $CMRR = A_v/A_{cm}$.

(NOTE: CMRR is expressed in decibels; the higher the rating the better the common-mode rejection.)

V. Advantages of active filters

A. An important advantage of active filters as opposed to passive filters is their low cost.

B. No insertion loss is evident in an active filter because gain is provided by the op amp.

C. Ease of tuning is present over a wide range of frequencies without altering the desired response.

D. Isolation is provided by the very high input impedance and low output impedance of the op amp.

E. Variable Q filters are available for the purpose of providing wide capabilities in Q adjustment.

VI. Disadvantages of active filters

A. Active filters require a power supply to operate the operational amplifier.

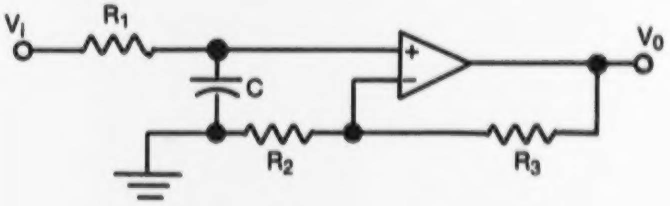
B. All op amps have a frequency response limit, therefore the type of op amp selected will limit the filter frequency response of the active filter.

INFORMATION SHEET

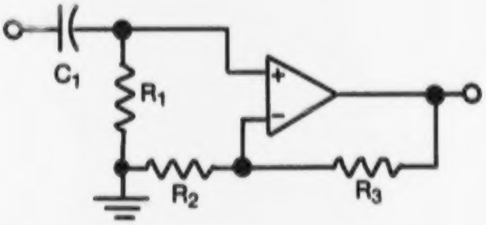
VII. Types of active filters

A. First-order active filters consist of an op amp and a filter network and usually take one of three forms:

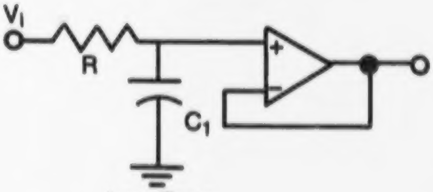
1. First-order low-pass filter


Vi
R1
C
R2
R3
Vo
+
−

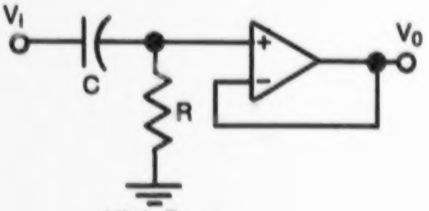
2. First-order high-pass filter



3. Unity-gain filters

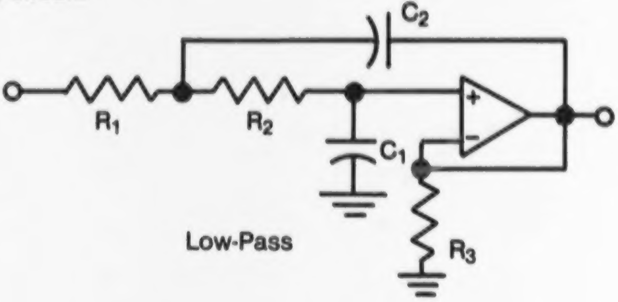


Low-Pass



High-Pass

B. The simplest second-order filter is the voltage-controlled voltage source (VCVS) circuit.

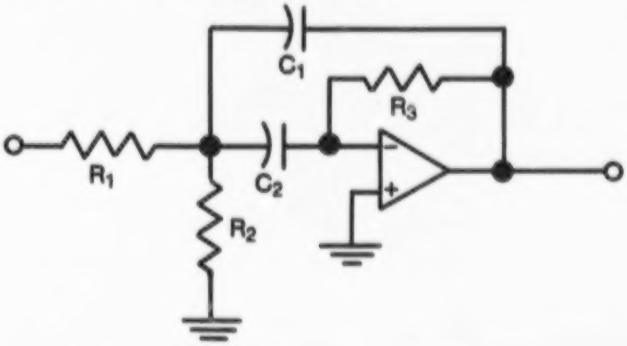

C2
R1
R2
C1
R3
+
−

Low-Pass

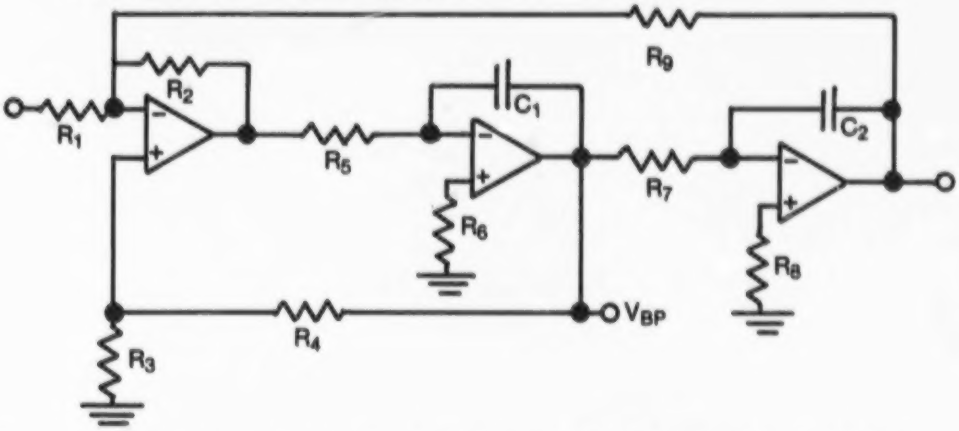
INFORMATION SHEET

C. An active bandpass filter may be constructed by combining low and high-pass filters components.

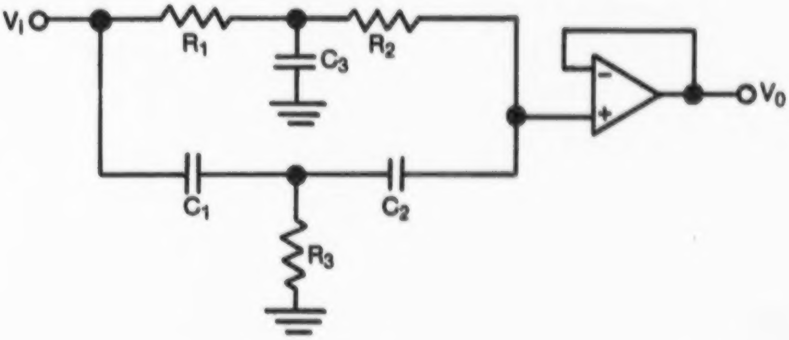
1. R1-C1 provide low-pass filtering.
2. R2-C2 provide high-pass filtering.


C1
R3
R1
C2
R2
−
+

D. A state-variable filter is a multiple feedback filter using several op amps, has one input, and has three outputs that simultaneously provide low-pass, high-pass, and bandpass filtering.


R9
R2
R1
C1
C2
R5
R7
R6
R8
R4
R3
V_{BP}
−
+

E. A commonly used active filter to reject a band of frequencies is the twin-T notch filter.

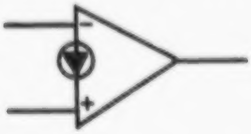

V_i
R1
R2
C3
V_0
C1
C2
R3
−
+

INFORMATION SHEET

VIII. Norton amplifier characteristics and circuits

A. Norton amplifiers may be used in many DC circuits but are primarily designed for use in AC amplifier circuits that operate from a single power supply.

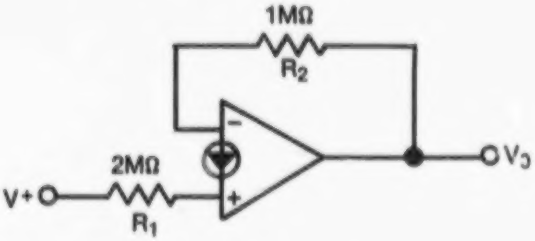
1. The schematic symbol for a Norton amplifier is



2. Sometimes called a current-differencing amplifier

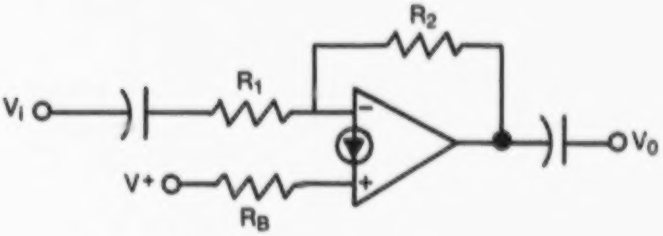
3. Current driven device

4. Current-mirror biasing sets the quiescent DC output voltage at one-half the power supply voltage



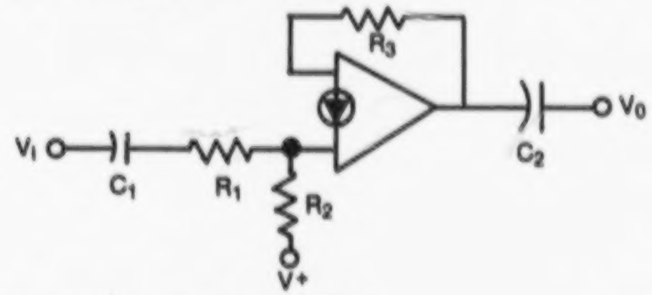
B. Norton amplifiers may be arranged in a number of circuit configurations.

1. Inverting Norton amplifier

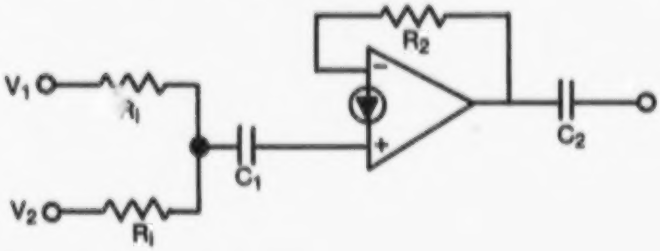


INFORMATION SHEET

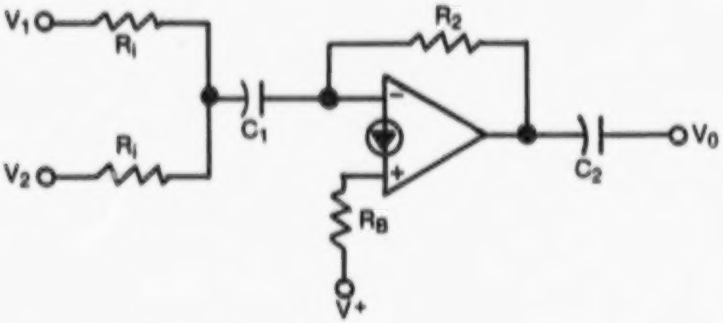
2. Noninverting Norton amplifier


R3
Vi
C1
R1
R2
V+
C2
Vo

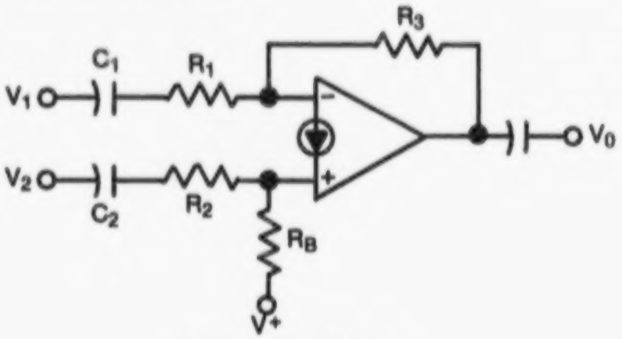
3. Noninverting summing amplifier


R2
V1
Ri
V2
Ri
C1
−
+
C2

4. Inverting summing amplifier


V1
Ri
V2
Ri
C1
R2
−
+
RB
V+
C2
Vo

5. Difference amplifier


R3
C1
R1
V1
V2
C2
R2
−
+
RB
V+
Vo

INFORMATION SHEET

IX. **Operational characteristics of switching regulator circuits**

A. The basic action of a switching regulator is to repeatedly switch a transistor completely on and off at a controlled rate.

1. If the transistor is switched at a high frequency, the output will be high.

2. The duty cycle of the pulse supplied to the transistor will also vary the output.

(NOTE: The duty cycle is the ratio of a pulse's on-time to the total pulse time.)

B. There are basically three configurations of switching regulators:

1. Step-down

2. Step-up

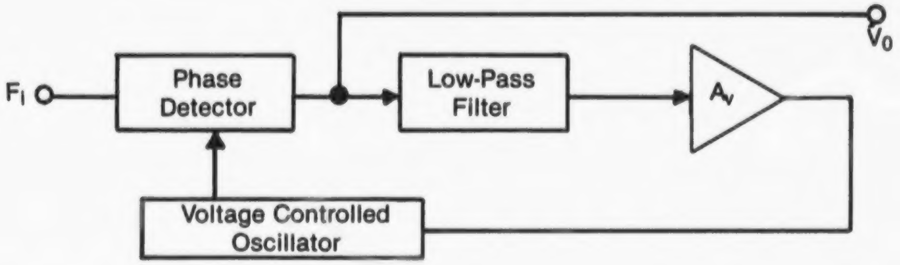
3. Voltage inverting

C. Efficiency of switching supplies is commonly 80 to 90 percent.

D. A switching regulator IC typically has built-in overload protection that senses excessive current drain and shuts the supply completely down when overload occurs.

X. **Characteristics of phase-locked loops**

A. A phase-locked loop (PLL) circuit contains an electronic feedback circuit that includes a phase detector (comparator), a low-pass filter, a voltage-controlled oscillator (VCO), and a DC amplifier.



INFORMATION SHEET

1. The phase detector generates the DC control voltage.

2. The low-pass filter network determines the dynamic performance of the loop by removing the AC signal variations from the phase detector and controls the lock, capture, and bandwidth of the loop.

3. The DC amplifier increases the level of the filtered DC control voltage to the level needed for the varactor in the VCO.

4. The VCO circuit provides an automatically tuned oscillator frequency.

B. Three operating modes of a phase-locked loop are free-running, capture, and phase-locked (frequently called lock-in or tracking).

1. The range over which the PLL can follow the incoming frequency is called the lock or tracking range.

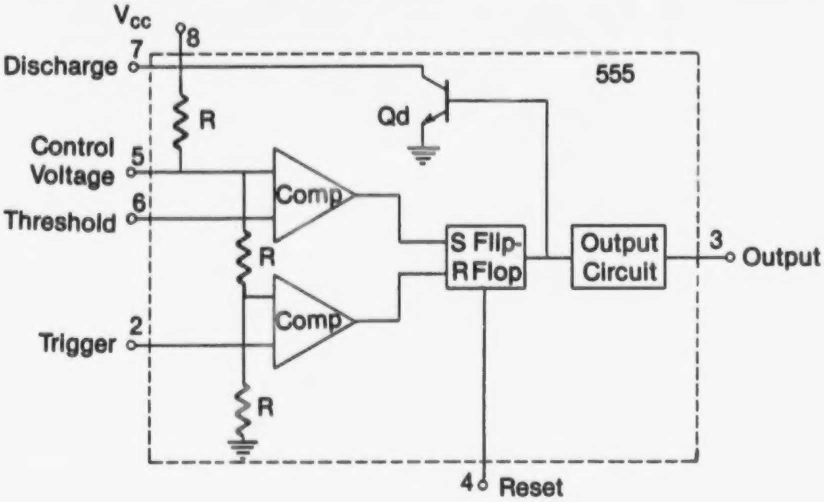
2. The capture range is the bandwidth over which the PLL can accomplish lock-in.

   (NOTE: The capture range can never be wider than the lock range.)

3. The VCO is free-running when lock-in is not present.

XI. Timer circuit configurations using the 555 timer IC

A. The 555 timer IC consists basically of a flip-flop, two comparators, a voltage divider, and a discharge transistor.



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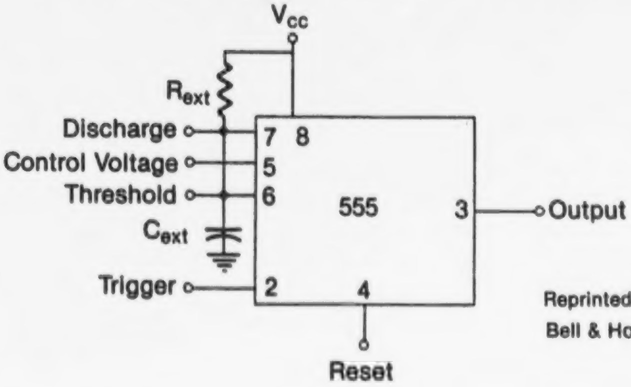
INFORMATION SHEET

B. One-shot monostable multivibration operation may be achieved by connecting an external resistor and capacitor to a 555 timer IC.


V_{cc}
R_{ext}
Discharge
Control Voltage
Threshold
C_{ext}
Trigger
7
8
5
6
555
3
Output
2
4
Reset

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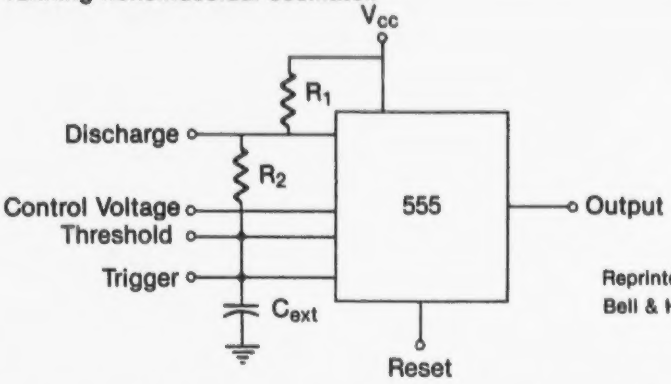
C. The 555 timer may be connected to operate in the asatable mode as a free-running nonsinusoidal oscillator.


V_{cc}
R_1
Discharge
R_2
Control Voltage
Threshold
Trigger
555
Output
C_{ext}
Reset

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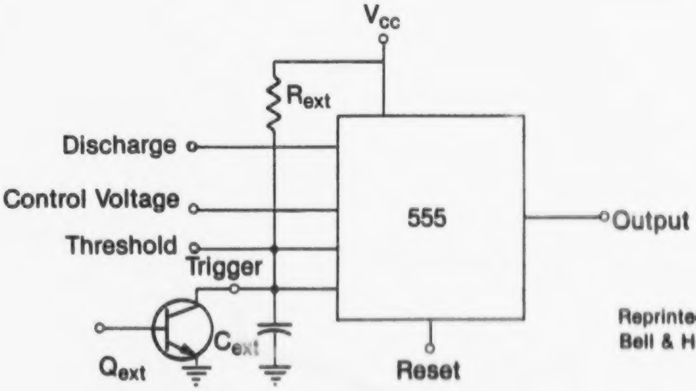
D. The 555 timer IC may be configured for time delay operation with the connection of an external resistor, capacitor, and transistor.


V_{cc}
R_{ext}
Discharge
Control Voltage
555
Output
Threshold
Trigger
C_{ext}
Q_{ext}
Reset

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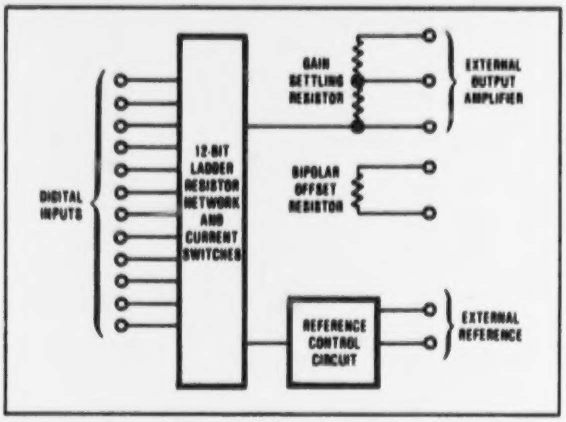
INFORMATION SHEET

XII. Circuits used in conversion between analog and digital technologies

A. Digital-to-analog converter (DAC) circuits convert digital information to analog form and are available as integrated circuits for a wide range of operating characteristics.

(NOTE: Numerous product data sheets for digital-to-analog converter IC's are available in publications such as Burr-Brown's *Integrated Circuits Data Book.*)


GAIN SETTLING RESISTOR
EXTERNAL OUTPUT AMPLIFIER
DIGITAL INPUTS
12-BIT LADDER RESISTOR NETWORK AND CURRENT SWITCHES
BIPOLAR OFFSET RESISTOR
REFERENCE CONTROL CIRCUIT
EXTERNAL REFERENCE

Burr-Brown DAC 10HT General Purpose D-A Converter

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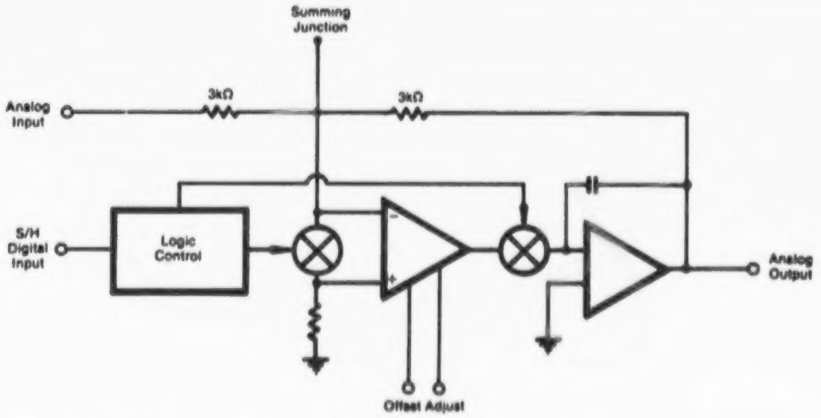
B. Specifications may vary for individual DACs but many common specifications are listed for all.

1. Linearity describes the performance of the DAC in terms of its accuracy.
2. Differential linearity error is the deviation from an ideal 1-LSB change in the output from one adjacent output state to the next output state.
3. Monotonicity assures that the analog output will increase or remain the same for increasing input digital codes.
4. Gain drift is a measure of the change in the full-scale range output over a specified temperature range.
5. Offset drift is a measure of the change in output with all ones applied to the input over a specified temperature range.
6. Settling time of a DAC is the total time required for the output to settle on its final value after a change in input.

INFORMATION SHEET

C. Sample-and-hold circuits are used to periodically sample a voltage and then hold constant for input to an analog-to-digital converter.


Summing Junction
3kΩ
3kΩ
Analog Input
S/H Digital Input
Logic Control
Analog Output
Offset Adjust

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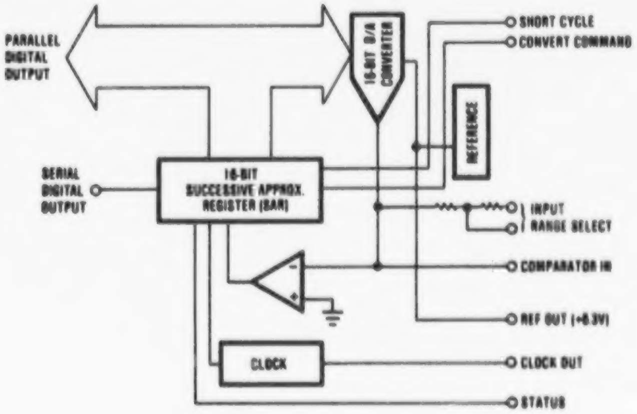
D. Analog-to-digital converters (ADC) are used to convert an analog signal to an equivalent digital signal.

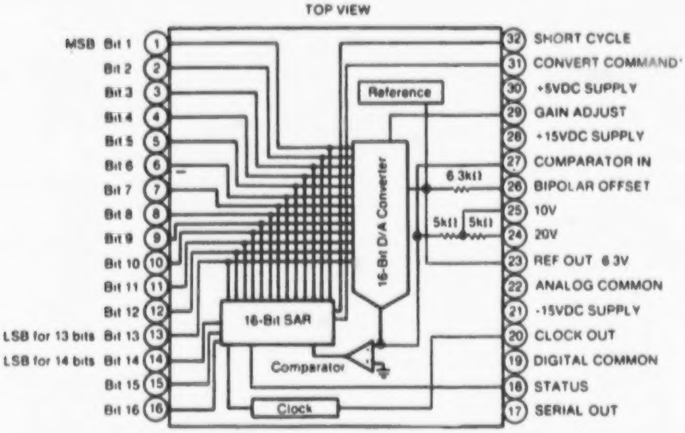
E. Critical specifications for an ADC are similar to the DAC, i.e. linearity, drift, gain and offset errors, and the conversion-speed effects on accuracy.

INFORMATION SHEET

F. The most widely used analog-to-digital converter is the successive-approximation type.


PARALLEL DIGITAL OUTPUT
16-BIT D/A CONVERTER
SHORT CYCLE
CONVERT COMMAND
REFERENCE
SERIAL DIGITAL OUTPUT
16-BIT SUCCESSIVE APPROX. REGISTER (SAR)
INPUT
RANGE SELECT
COMPARATOR IN
REF OUT (+6.3V)
CLOCK
CLOCK OUT
STATUS

Burr-Brown ADC72 A-D Converter


TOP VIEW
MSB Bit 1
Bit 2
Bit 3
Bit 4
Bit 5
Bit 6
Bit 7
Bit 8
Bit 9
Bit 10
Bit 11
Bit 12
LSB for 13 bits Bit 13
LSB for 14 bits Bit 14
Bit 15
Bit 16
Reference
16-Bit D/A Converter
6.3kΩ
5kΩ
5kΩ
16-Bit SAR
Comparator
Clock
SHORT CYCLE
CONVERT COMMAND*
+5VDC SUPPLY
GAIN ADJUST
+15VDC SUPPLY
COMPARATOR IN
BIPOLAR OFFSET
10V
20V
REF OUT 6.3V
ANALOG COMMON
-15VDC SUPPLY
CLOCK OUT
DIGITAL COMMON
STATUS
SERIAL OUT

*If an external clock is used, connect the clock to pin 31 CONVERT COMMAND

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INTEGRATED CIRCUITS
UNIT IV

JOB SHEET #1 — CONSTRUCT A NONINVERTING NORTON AMPLIFIER AND DETERMINE PHASE RELATIONSHIP AND GAIN

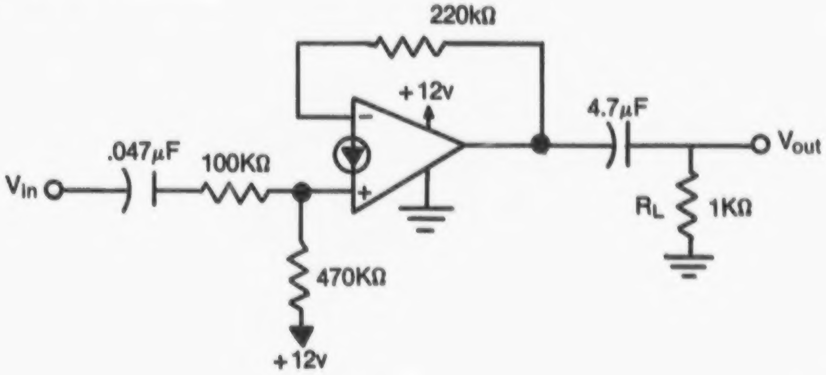
A. Equipment and materials needed

1. 4.7 μF capacitor
2. .047 μF capacitor
3. 1 KΩ resistor
4. 100 KΩ resistor
5. 220 KΩ resistor
6. 470 KΩ resistor
7. LM3900 quad op-amp or equivalent
8. Oscilloscope, dual-trace
9. Audio signal generator or function generator
10. DC power supply
11. Digital voltmeter

B. Procedure

1. Construct the following circuit. (Figure 1)

FIGURE 1



JOB SHEET #1

2. Adjust oscilloscope to read .2 volts per division on both channels and time base setting for 1 msec per division with DC coupling to inputs.

3. Apply power to circuit.

4. Measure DC voltage at inputs, – and + terminals of op-amp.

   – ____________ v   + ____________ v

5. Measure DC voltage at op-amp output – ____________ v

6. Apply .2V p-p, 400 Hz sine wave to circuit input.

7. Using your oscilloscope, compare the phase relationship between input and output.

   ____

   ____

8. Measure the peak-to-peak output voltage and determine the voltage gain.

   Av = ____________

9. Dismantle the circuit and return materials and equipment to their proper storage location.

INTEGRATED CIRCUITS
UNIT IV

JOB SHEET #2 — CONSTRUCT AN INVERTING NORTON AMPLIFIER AND DETERMINE PHASE RELATIONSHIP AND GAIN

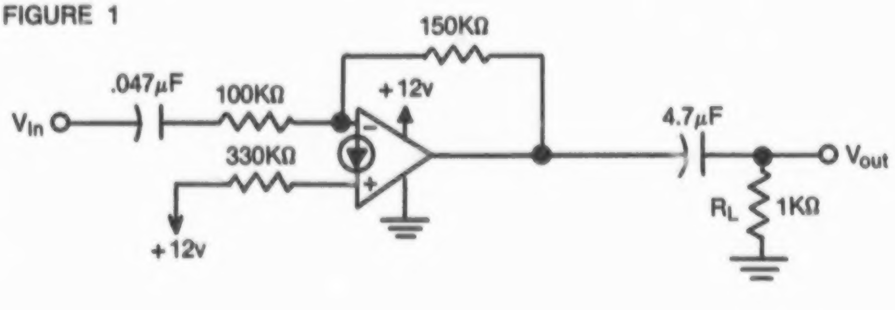
A. Equipment and materials needed

1. LM3900 quad op-amp or equivalent
2. 1 KΩ resistor
3. 100 KΩ resistor
4. 150 KΩ resistor
5. 330 KΩ resistor
6. .047 μF capacitor
7. 4.7 μF capacitor
8. Oscilloscope
9. Power supply
10. Digital voltmeter
11. Function generator

B. Procedure

1. Construct the following circuit. (Figure 1)

FIGURE 1



2. Set oscilloscope for .1 volt/division on both channels and time base for 1 msec/division.

JOB SHEET #2

3. Apply power to circuit.

4. Measure DC voltage at the − and + inputs to op-amp.

   − ____________ v   + ____________ v

5. Measure voltage at output of op-amp.

   ____________ v

6. Apply .4 volt p-p, 500 Hz sine wave to circuit input.

7. Measure peak-to-peak output voltage.

   Vout = ____________

8. Determine the voltage gain of the circuit.

   Gain = ____________

9. Using your oscilloscope, compare the phase relationship of output and input.

10. Dismantle the circuit and return materials and equipment to their proper storage location.

INTEGRATED CIRCUITS
UNIT IV

JOB SHEET #1 PRACTICAL TEST — CONSTRUCT A NONINVERTING NORTON AMPLIFIER AND DETERMINE PHASE RELATIONSHIP AND GAIN

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools, equipment, and materials.	______	______
2. Properly constructed circuit.	______	______
3. Properly set test equipment.	______	______
4. Demonstrated proper handling of integrated circuits.	______	______
5. Obtained measurements within acceptable tolerances.	______	______
6. Correctly determined gain of the circuit.	______	______
7. Dismantled circuit in orderly manner.	______	______
8. Cleaned the work area.	______	______
9. Performed the tasks in a timely manner (__hrs. __min. __sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Construct circuit	Correct			Incorrect
	4	3	2	1
Adjust test instruments	Proper adjustment			Improper adjustment
	4	3	2	1
Phase comparison	Correct phase			Incorrect phase
	4	3	2	1
Determine gain	Within tolerance			Incorrect

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INTEGRATED CIRCUITS
UNIT IV

JOB SHEET #2 PRACTICAL TEST — CONSTRUCT AN INVERTING NORTON AMPLIFIER AND DETERMINE PHASE RELATIONSHIP AND GAIN

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools, equipment, and materials.	______	______
2. Properly constructed circuit.	______	______
3. Properly set test equipment.	______	______
4. Demonstrated proper handling of integrated circuits.	______	______
5. Obtained measurements within acceptable tolerances.	______	______
6. Correctly determined gain of the circuit.	______	______
7. Dismantled circuit in orderly manner.	______	______
8. Cleaned the work area.	______	______
9. Performed the tasks in a timely manner (__hrs. __min. __sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Construct circuit	Correct			Incorrect
	4	3	2	1
Adjust test instruments	Proper adjustment			Improper adjustment
	4	3	2	1
Phase comparison	Correct phase			Incorrect phase
	4	3	2	1
Determine gain	Within tolerance			Incorrect

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INTEGRATED CIRCUITS
UNIT IV

NAME ____________________________ SCORE ______________________

TEST

1. Match the terms on the right with their correct definitions.

______a. A closed-loop electronic circuit that contains a phase detector, low-pass filter, DC amplifier, and a voltage-controlled oscillator in a feedback loop

______b. A complete circuit consisting of a number of separate component parts manufactured as a single microchip package

______c. Voltages of equal amplitude and frequency, in-phase, and applied to both inputs of a differential amplifier

______d. An amplifier that has two inputs and amplifies the difference between inputs to produce an output

______e. Filter that contains an active component such as an operational amplifier that introduces some signal gain

______f. An amplifier that exhibits a very high gain, high input and low output impedances, has a good rejection of common-mode signals, and has differential inputs

______g. A current driven operational amplifier circuit that amplifies AC signals

______h. An amplifier that has an output signal 180 degrees out of phase with the input signal

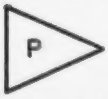
______i. An amplifier circuit with an output that is the sum of individual voltages applied through a resistive network to the (–) input of an op amp

1. Active filter
2. Common-mode signals
3. Differential amplifier
4. Integrated circuit
5. Inverting amplifier
6. Norton amplifier
7. Operational amplifier
8. Phase-locked-loop
9. Summing amplifier

TEST

2. Select true statements concerning basic input parameters of the operational amplifier by placing an "X" in the blanks preceding the true statements.

______a. The symbol for an operational amplifier (inverting type) is



______b. Input resistance of an op amp is less than one megohm.

______c. Input capacitance of an op amp is typically less than 2 pF.

______d. Input bias current of an op amp is the average of the two input current, typically in the microampere range, and is held low by the high input resistance.

______e. Input offset current of an op amp is the difference of the two input bias currents when the output voltage is zero.

______f. Input offset voltage is the voltage that is applied to one of the input terminals to give a high positive voltage output.

______g. Input voltage range is the range of voltage common to both inputs and ground (common-mode input voltage).

______h. Drift is the change in offset current and offset voltage caused by temperature changes.

______i. Input differential range is the maximum difference signal that may be applied safely to the op amp input terminals.

3. Complete the following statements concerning the output parameters of the operational amplifier by inserting the word that best completes each statement.

a. Output ______________ is the resistance looking into to output terminal and is a relatively low value, varying from a few ohms to a few thousand ohms.

b. Output short-circuit current is the ______________ output current that the op amp can deliver to the circuit load.

c. Output voltage swing is the maximum peak voltage that the op amp can supply without ______________ or clipping.

4. Complete the following statements concerning the dynamic parameters of the operational amplifier by inserting the word(s) that best completes each statement.

a. The ______________-______________ voltage gain is the ratio of the output voltage to the input voltage without external feedback and at a frequency of zero hertz.

b. ______________-______________ voltage gain is the ratio of the maximum voltage swing to the change in the input voltage required to drive the output from zero to a specified voltage.

TEST

c. The ____________ is the time rate of change of the output voltage at unity gain.

d. The ____________-____________ product is equal to the unity gain frequency and indicates the upper useful frequency of the circuit and gives a means of determining the bandwidth for any given gain.

e. ____________-____________ ____________ ____________ is the ratio of the common-mode input voltage to the generated output voltage and is a measure of the ability of the op amp to reject common-mode signals while amplifying differential signals.

5. List five advantages of active filters.

a. ____

b. ____

c. ____

d. ____

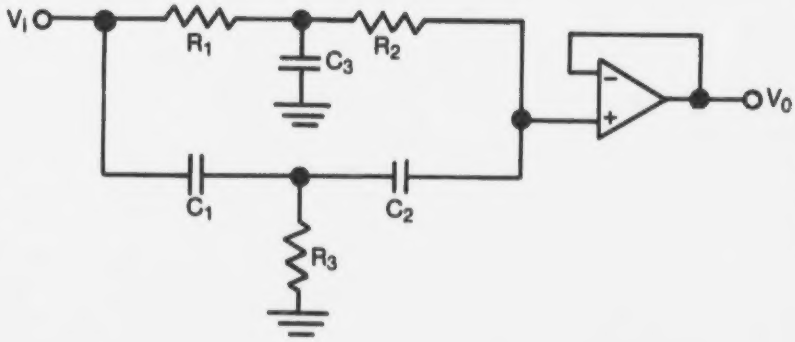
e. ____

6. List two disadvantages of active filters.

a. ____

b. ____

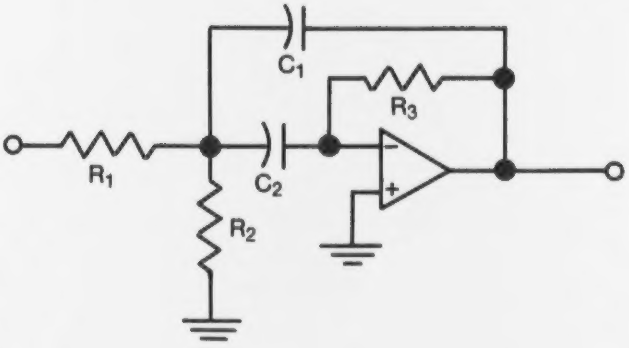
7. Match types of active filters on the right with their schematic diagrams.



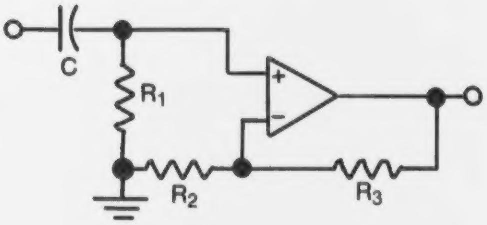
1. First-order low-pass filter
2. First-order high-pass filter
3. Twin-T notch filter
4. Active bandpass filter

_____a.

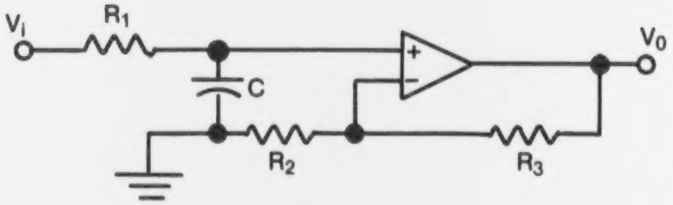
TEST



_____b.



_____c.



_____d.

8. Complete the following statements concerning Norton amplifier characteristics and circuits by inserting the word or diagram that best completes each statement.

   a. _____________ amplifiers may be used in many DC circuits but are primarily designed for use in AC amplifier circuits that operate from a single power supply.

   b. The schematic symbol for a Norton amplifier is: _____________.

   c. A Norton amplifier is sometimes called a current-_____________ amplifier.

TEST

d. The Norton amplifier is a ____________ driven device.

e. Current-mirror biasing sets the ____________ DC output voltage at one-half the power supply voltage.

9. Complete the following statements concerning the operational characteristics of switching regulator circuits by inserting the words/numbers that best complete each statement.

   a. The basic action of a switching regulator is to repeatedly switch a transistor completely ____________ and ____________ at a controlled rate.

   b. There are basically three configurations of switching regulators: ____________-____________, ____________-____________, and ____________ inverting.

   c. Efficiency of switching supplies is commonly ____________ to ____________ percent.

   d. A switching regulator IC typically has built-in ____________ protection that senses excessive current drain and shuts the supply completely down when overload occurs.

10. Complete statements concerning the characteristics of phase-locked loops by inserting the word(s) that best completes each statement.

   a. The ____________ detector generates the DC control voltage.

   b. The ____________-____________ filter network determines the dynamic performance of the loop by removing the ac signal variations from the ____________ detector and controls the lock, capture, and bandwidth of the loop.

   c. The DC ____________ increases the level of the filtered DC control voltage to the level needed for the varactor in the VCO.

   d. The voltage-controlled ____________ circuit provides an automatically tuned oscillator output frequency.

   e. Three operating modes of a phase-locked loop are ____________-____________, ____________, and ____________-____________ or tracking modes.

11. Complete the following statements concerning timer circuit configurations using the 555 timer IC by inserting the word(s) that best complete each statement.

   a. The 555 timer IC consists basically of a ____________, two ____________, a ____________ divider, and a discharge ____________.

   b. The 555 timer IC may be configured to operate as a one-shot monostable ____________, time delay circuit, or asatable free-running nonsinusoidal ____________, by connecting external resistors, capacitors, or transistor of various values and types to the 555 IC.

TEST

12. Select true statements concerning circuits used in conversion between analog and digital technologies by placing an "X" in the blanks preceding the true statements.

_____a. Digital-to-analog converter (DAC) circuits convert digital information to analog form.

_____b. Monotonicity describes the performance of the DAC in terms of its accuracy.

_____c. Differential linearity error is the deviation from an ideal 1-LSB change in the output from one adjacent output state to the next output state.

_____d. Linearity assures that the analog output will increase or remain the same for increasing input digital codes.

_____e. Offset drift is a measure of the change in the full-scale range output over a specified temperature range.

_____f. Gain drift is a measure of the change in output with all ones applied to the input over a specified temperature range.

_____g. Settling time of a DAC is the total time required for the output to settle on its final value after a change in input.

_____h. Sample-and-hold circuits are used to periodically sample a voltage and then hold constant for input to an analog-to-digital converter.

_____i. Analog-to-digital converters (ADC) are used to convert an analog signal to an equivalent digital signal.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Demonstrate the ability to:

a. Construct a noninverting Norton amplifier and determine phase relationships and gain. (Job Sheet #1)

b. Construct an inverting Norton amplifier and determine phase relationships and gain. (Job Sheet #2)

INTEGRATED CIRCUITS
UNIT IV

ANSWERS TO TEST

1. a. 8
   b. 4
   c. 2
   d. 3
   e. 1
   f. 7
   g. 6
   h. 5
   i. 9

2. c, d, e, g

3. a. Resistance
   b. Maximum
   c. Saturation

4. a. Open-loop
   b. Large-signal
   c. Slew rate
   d. Gain-bandwidth
   e. Common-mode rejection ratio

5. Answers may be in any order

   a. Low cost
   b. No insertion loss
   c. Ease of tuning over wide frequency range
   d. Isolation between input and output
   e. Variable Q filters are available

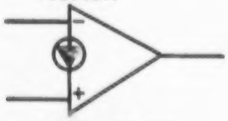
6. a. Need power supply to operate
   b. Limited by frequency response of the device

7. a. 3
   b. 4
   c. 2
   d. 1

ANSWERS TO TEST

a. Norton

8. b.



c. Differencing
d. Current
e. Quiescent

9. a. On, off
b. Step-down, step-up, voltage inverting
c. 80, 90
d. Overload

10. a. Phase
b. Low-pass
c. Amplifier
d. Oscillator
e. Free-running, capture, phase-locked

11. a. Flip-flop, comparators, voltage, transistor
b. Multivibrator, oscillator

12. a, c, g, h, i

13. Performance skills evaluated according to industry standards and to the satisfaction of the instructor

MICROPROCESSORS
UNIT V

UNIT OBJECTIVE

After completion of this unit, the student should be able to apply theoretical knowledge of microprocessors and microcomputers and take measurements from system bus of a microcomputer. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to microprocessors with their correct definitions.
2. Complete statements concerning sections of a microcomputer with their functions.
3. Match the sections of the CPU with their functions.
4. List three ways information flows in a microprocessor.
5. Match memory devices with their functions.
6. Complete statements concerning busses and their functions.
7. Complete statements concerning the characteristics of the data bus.
8. Complete statements concerning the characteristics of the address bus.
9. Select true statements concerning the characteristics of the control bus.
10. Complete statements concerning the clock and clock timing characteristics.
11. Describe the functions of interrupts.

OBJECTIVE SHEET

12. Arrange in order the steps in a microcomputer operating cycle.
13. Complete statements concerning characteristics of machine language.
14. Complete statements concerning the characteristics of assembler language.
15. Name two standards of communications for digital information.
16. Demonstrate the ability to:
    a. Write and run a machine language driver program to check a read/write memory (RAM) location. (Job Sheet #1)
    b. Use a digital voltmeter to test supply voltages on a microcomputer system bus. (Job Sheet #2)
    c. Use an oscilloscope to check a microcomputer clock system. (Job Sheet #3)

MICROPROCESSORS
UNIT V

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheets.

F. Discuss information sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Review system architecture of various computers.
2. Provide instructions for each type of microprocessor available in your laboratory.
3. Tour facilities which use microprocessors to control equipment functions.
4. If different brands of computers are available, point out differences in design and capabilities.
5. Demonstrate proper care of microcomputers.
6. Review number systems including hexadecimal prior to completion of job sheets.
7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Administer test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Brown, A. O. *Advanced Microcomputer Service Technician.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, 1985.

B. Hall, Douglas V., *Microprocessors and Digital Systems.* Second Edition. New York: McGraw-Hill Book Company, 1983.

C. Ward, Dennis M. *Applied Digital Electronics.* Columbus, OH: Charles E. Merrill Publishing, 1982.

MICROPROCESSORS
UNIT V

INFORMATION SHEET

I. **Terms and definitions**

A. Address word — A binary word that the microprocessor uses as an address to determine the location of a memory or I/O word

B. Asynchronous — The condition in which the timing of a bit or binary word does not coincide with the signal source used in the system

C. Byte — A string of binary digits, usually eight; operated on as a basic unit by a digital computer

D. Data word — A binary word that the microprocessor manipulates internally by moving, storing, or performing an operation on to accomplish a desired result

E. Decrementing — Decreasing the contents of an address or register by one

F. Handshaking — An exchange of predetermined signals when a connection is made between two data-set devices

G. Incrementing — Increasing the contents of an address or register by one

H. Interface — The point where two components connect within a system and/or the device used to make the connection

I. Microcomputer — A computer system whose processing unit is a microprocessor that contains memory and input-output facilities

J. Microprocessor — The arithmetic logic unit, registers, and timing and decoding circuitry usually contained in a single integrated circuit that control computer activity

K. Mnemonics — Acronyms chosen to aid the programmer or technician

Example: MPY for multiply

L. Peripheral — Any device such as a disk drive, printer, modem, or video display added to a microcomputer to provide increased capacity for handling, storing, or presenting data

M. Protocol — A communications exchange accomplished with software

N. Synchronous — The timing of a bit or binary word so that it coincides with a precisely timed signal source

INFORMATION SHEET

II. **Sections of a microcomputer and their functions** (Transparency 1)

   A. The central processing unit (CPU) is the heart of the microcomputer system and contains the arithmetic logic unit (ALU), the control circuitry, some registers, and a program/address counter.

   (NOTE: CPU is used to describe the central processing unit in all computers, large and small. In microcomputers, the CPU may be a single chip — the microprocessor chip.)

   B. The memory section usually contains RAM and ROM and magnetic memory used for temporary or permanent storage of binary information.

   C. The input-output (I/O) section contains circuitry to provide the interface to the peripheral devices outside the computer.

   D. Busses are a system of wires or printed circuits used to connect the CPU to the remainder of the system.

   E. Registers are internal devices where stored information is manipulated as a group of bits.

III. **Sections of the CPU and their functions** (Transparency 2)

   A. The control section of the microprocessor receives binary instructions from the data bus, decodes them, and processes clock timing and interrupt signals.

   B. The register section contains the ALU, the program counter, the index and flag registers, the accumulators, and the stack pointer.

      1. The arithmetic logic unit (ALU) performs calculations, sends information to the accumulator, and initiates the output to the flag register.

      2. The accumulator stores quantities to be operated on by the ALU and receives the results of the arithmetic operation performed by the ALU.

      3. The program counter controls the step-by-step progress as the CPU executes a program.

      4. The index register performs the task of indexing in one direction or the other through memory to help accomplish a repetitive function. It is unique in that, when instructed, it will add (increment) or subtract (decrement) from its contents by 1.

      5. The stack pointer keeps track of where things are when stacking in memory occurs and points the programmer to the location of where information is stored (stacked).

      6. The flag register contains bits of information that indicate the status of the microprocessor at the end of the last instruction that was executed.

INFORMATION SHEET

IV. **Ways information flows in a microprocessor** (Transparency 3)

A. Information flows through the microprocessor in one of three ways:

1. As an **ADDRESS** word which originates at the microprocessor and flows to the remaining parts of the system
2. As a **DATA** word which flows in and out of the microprocessor to and from the system
3. As **CONTROL** information which flows in and out of the microprocessor

B. To start information flow an instruction word is sent to the microprocessor via the data line in the data bus.

C. The information contained in the instruction will be a binary word from the data bus and is deposited in the register generally known as the instruction register.

D. The instruction word, after it has been received from the data bus, will be held or "latched" into the instruction decode section of the microprocessor where it is decoded.

V. **Memory devices and their functions**

A. Read only memory (ROM is a nonvolatile type (contents do not change and normally cannot be altered) in integrated circuit form which has been programmed to control the basic operations of the system and such other decoding functions as reading the keyboard and controlling video information to display; retains its contents when power is turned off.

B. Erasable programmable read only memory (EPROM) is a ROM that may be erased by ultraviolet light and reprogrammed by the user; retains its contents when power is turned off.

C. Random access memory (RAM) is a read and write memory that may be changed at any time, but loses its content when power is turned off.

1. Static read/write memory (SRAM) retains stored contents until it is altered or power is turned off.
2. Dynamic read/write memory (DRAM) retains stored contents only one to two milliseconds, must be continually refreshed if it is to keep its contents, and loses all contents when power is turned off.

(NOTE: Peripheral devices such as magnetic tape units and floppy disk units allow for permanent storage of information.)

D. Electronic alterable programmable, read only memory (EAPROM) is a ROM whose contents may be altered quickly by electrical erasure.

INFORMATION SHEET

VI. **Busses and their functions**

A. Busses carry multiple signals from one part of a circuit or system to another part in such a way that the arrival of all bits of information are timed to coincide.

B. Bus circuitry may be one of several forms:

1. A pathway in silicon
2. A printed circuit pathway
3. A wire conductor

C. Most busses in microcomputers are parallel synchronous busses to indicate the element of timing essential to their functions.

D. Microcomputers contain a system bus (such as the S-100, IEEE 488) into which expansion and interface board or cards that enhance or modify the systems capabilities may be placed.

E. Data busses, address busses, and control busses are contained within the microcomputer to transfer and control data.

VII. **Characteristics of the data bus**

(NOTE: Multiple bit systems such as 16- and 32-bits are now available.)

A. The data bus carries information in 8-bit binary words to and from the microprocessor.

B. The 8-bit binary word is synchronized by the system clock and is bi-directional.

C. The binary word on the data bus may contain an instruction, data, or address information.

D. The data bus may be a multiconductor cable or PC board pathway and consists of parallel conductors that simultaneously carry 8 binary 1's or 0's or combinations of the two binary digits.

VIII. **Characteristics of the address bus**

A. The address bus carries addresses generated by the microprocessor to a designated device such as RAM, ROM, or I/O device.

B. Information carried on the address bus may also identify the location within RAM, ROM, or I/O from which the microprocessor may receive information from or send information to.

C. The address bus may be a multiconductor cable or PC board that consists of 16 parallel lines that simultaneously carries a combination of 16 binary 1's and 0's.

INFORMATION SHEET

IX. Characteristics of the control bus

A. Specialized control bus functions vary from system to system.

B. The control bus controls the timing and direction of information.

C. Control signals are not as synchronized along the parallel lines as the data and address signals are.

D. The control bus usually carries clock pulses, read/write signals, and interrupt signals.

X. Clock and clock timing characteristics

A. Timing of a microprocessor or microcomputer system is accomplished with a clock circuit on the microprocessor chip or with a separate clock circuit.

B. The clock waveform is usually a two-phase, nonoverlapping type with two signals at the same frequency but starting at different times.

C. When one waveform is high the other is low with the waveforms identified as phase one (high) and phase two (low).

D. The clock provides timing signals to all parts of the system and does not need to be addressed.

E. The CPU controls the system busses and the clock controls timing to all of the system.

(NOTE: If either clock or CPU fails, the system is inoperative.)

F. The high-speed timing cycle may be manipulated by an interrupt signal from the operator of the computer or from an external peripheral device.

XI. Functions of interrupts

A. An interrupt is a signal from a piece of equipment that is requesting service by the microprocessor.

B. An interrupt will cause a microprocessor to stop what it is doing and perform some other operation that has been previously programmed.

C. Interrupts permit external asynchronous input into the microprocessor so that it may be used for multiple purposes.

XII. Steps in a microcomputer operating cycle

A. Before a program may be executed, the program counter must be set to a memory location that begins the program.

B. The CPU places the contents of the program counter on the address bus, then the program counter proceeds to the next sequential memory location where it stops until it receives instructions from the CPU decoder section.

INFORMATION SHEET

C. The address bus selects the contents of the memory specified and places the binary instruction that it finds onto the data bus.

D. The data bus carries its data to the instruction register of the CPU.

E. In the CPU, the decoder sets up the appropriate registers in response to the instruction that was placed in the instruction register.

F. After the registers are set up, one of these two operations normally occur:

1. The CPU may execute the program directly if no further data is required.

2. The CPU may require that the program counter send another address out on the system address bus to retrieve data from another memory address which may be required to complete the instruction cycle.

(NOTE: Refer to MAVCC's *Advanced Microcomputer Service Technician* for specific microprocessor architecture and instruction sets.)

XIII. **Characteristics of machine language**

A. Machine language requires that the computer operator specify actual memory addresses in the computer and machine codes that are understood by the computer control section.

B. It requires data necessary for the operation at the level the computer can understand, which is usually binary or hexadecimal.

C. It requires that an operator know the codes and the addressing modes of the instructions for a specific microprocessor chip because each chip has a different set of codes.

D. Most system troubleshooting routines are written in machine language.

E. It usually takes a longer time to write a program in machine language than in any other language, but the resulting program executes the fastest.

XIV. **Characteristics of assembler language**

A. Assembler language replaces machine codes with mnemonics.

B. Mnemonics are usually three or four-letter codes that may be abbreviations for the operation to be performed.

Example: ADC means add with carry, LDA means load the accumulator, ROR means rotate right

C. Addressing in assembly language is done by "labeling" rather than giving specific machine addresses.

INFORMATION SHEET

D. After a program is written in assembler language, the mnemonics and labels must be run through a program called an "assembler".

E. The assembler program will generate the machine code which will operate the computer.

F. It is easier to write a program with assembler language than with machine language and it is more generic in nature and does not require learning a new code for each different microprocessor chip.

G. Assembler language programming can be accomplished much faster than programming with machine language.

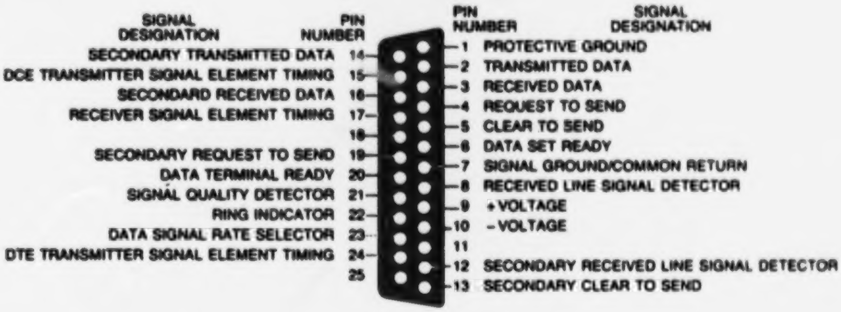
XV. Standards of communications for digital information

A. The RS-232C communications standard by the Electronics Industry Association is recommended as a guide for communicating digital information.

B. The RS-232C standard is specifically written for serial communications and has two major elements of importance:

1. The electrical and mechanical parameters involved, including the voltage levels that are acceptable and specific pin assignments for interconnections
2. The communications involved may include handshaking and the high and low bit signals used to indicate the beginning and end of the ASCII data word being transmitted

RS-232 Interface


SIGNAL DESIGNATION
PIN NUMBER
SECONDARY TRANSMITTED DATA 14
DCE TRANSMITTER SIGNAL ELEMENT TIMING 15
SECONDARD RECEIVED DATA 16
RECEIVER SIGNAL ELEMENT TIMING 17
18
SECONDARY REQUEST TO SEND 19
DATA TERMINAL READY 20
SIGNAL QUALITY DETECTOR 21
RING INDICATOR 22
DATA SIGNAL RATE SELECTOR 23
DTE TRANSMITTER SIGNAL ELEMENT TIMING 24
25
PIN NUMBER
SIGNAL DESIGNATION
1 PROTECTIVE GROUND
2 TRANSMITTED DATA
3 RECEIVED DATA
4 REQUEST TO SEND
5 CLEAR TO SEND
6 DATA SET READY
7 SIGNAL GROUND/COMMON RETURN
8 RECEIVED LINE SIGNAL DETECTOR
9 +VOLTAGE
10 -VOLTAGE
11
12 SECONDARY RECEIVED LINE SIGNAL DETECTOR
13 SECONDARY CLEAR TO SEND

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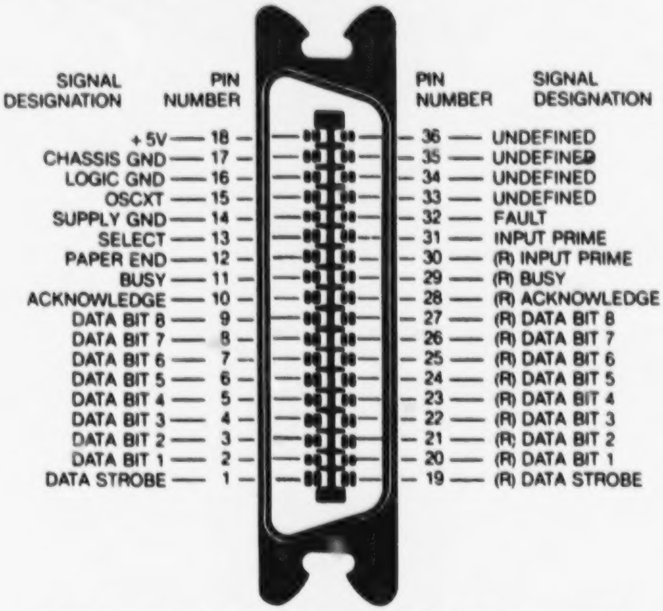
INFORMATION SHEET

C. The Centronics standard is an industry accepted guideline that is primarily for use in communicating digital information in parallel form.

Parallel Interface (Centronics type)



SIGNAL DESIGNATION	PIN NUMBER	PIN NUMBER	SIGNAL DESIGNATION
+5V	18	36	UNDEFINED
CHASSIS GND	17	35	UNDEFINED
LOGIC GND	16	34	UNDEFINED
OSCXT	15	33	UNDEFINED
SUPPLY GND	14	32	FAULT
SELECT	13	31	INPUT PRIME
PAPER END	12	30	(R) INPUT PRIME
BUSY	11	29	(R) BUSY
ACKNOWLEDGE	10	28	(R) ACKNOWLEDGE
DATA BIT 8	9	27	(R) DATA BIT 8
DATA BIT 7	8	26	(R) DATA BIT 7
DATA BIT 6	7	25	(R) DATA BIT 6
DATA BIT 5	6	24	(R) DATA BIT 5
DATA BIT 4	5	23	(R) DATA BIT 4
DATA BIT 3	4	22	(R) DATA BIT 3
DATA BIT 2	3	21	(R) DATA BIT 2
DATA BIT 1	2	20	(R) DATA BIT 1
DATA STROBE	1	19	(R) DATA STROBE

(R) INDICATES SIGNAL GROUND RETURN

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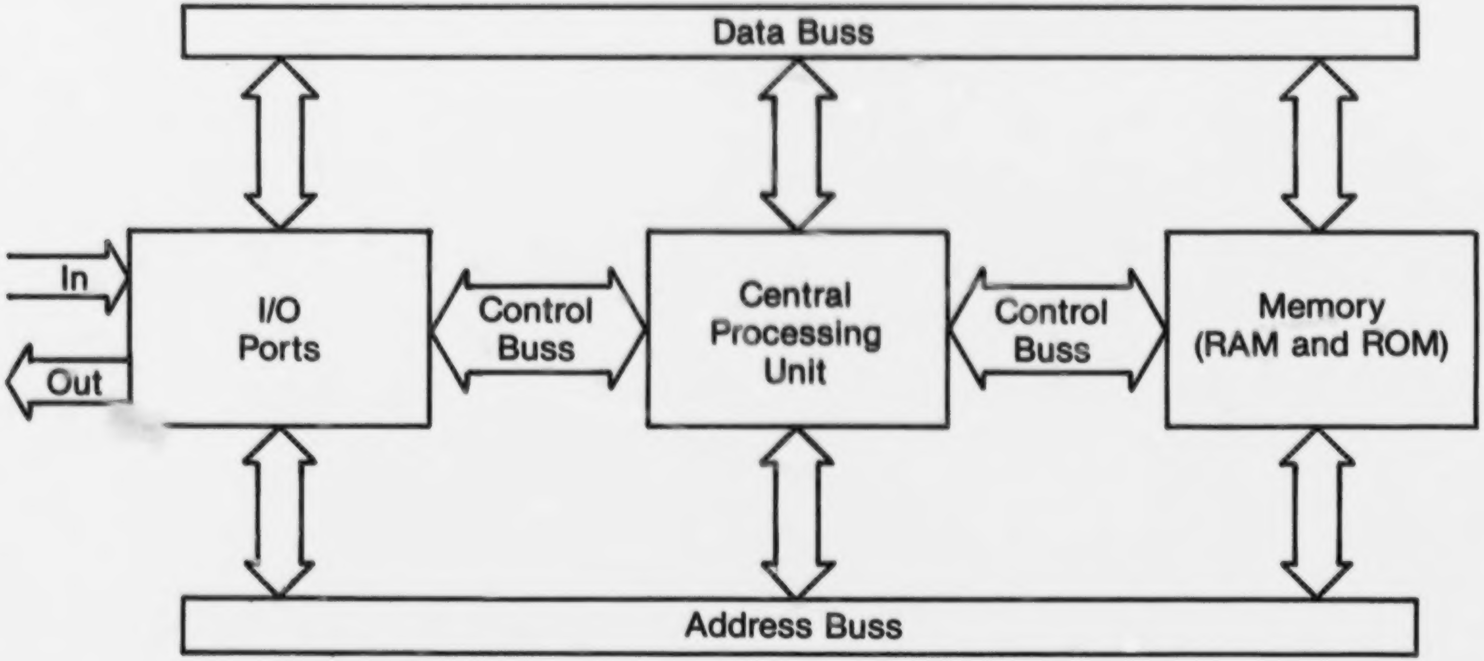
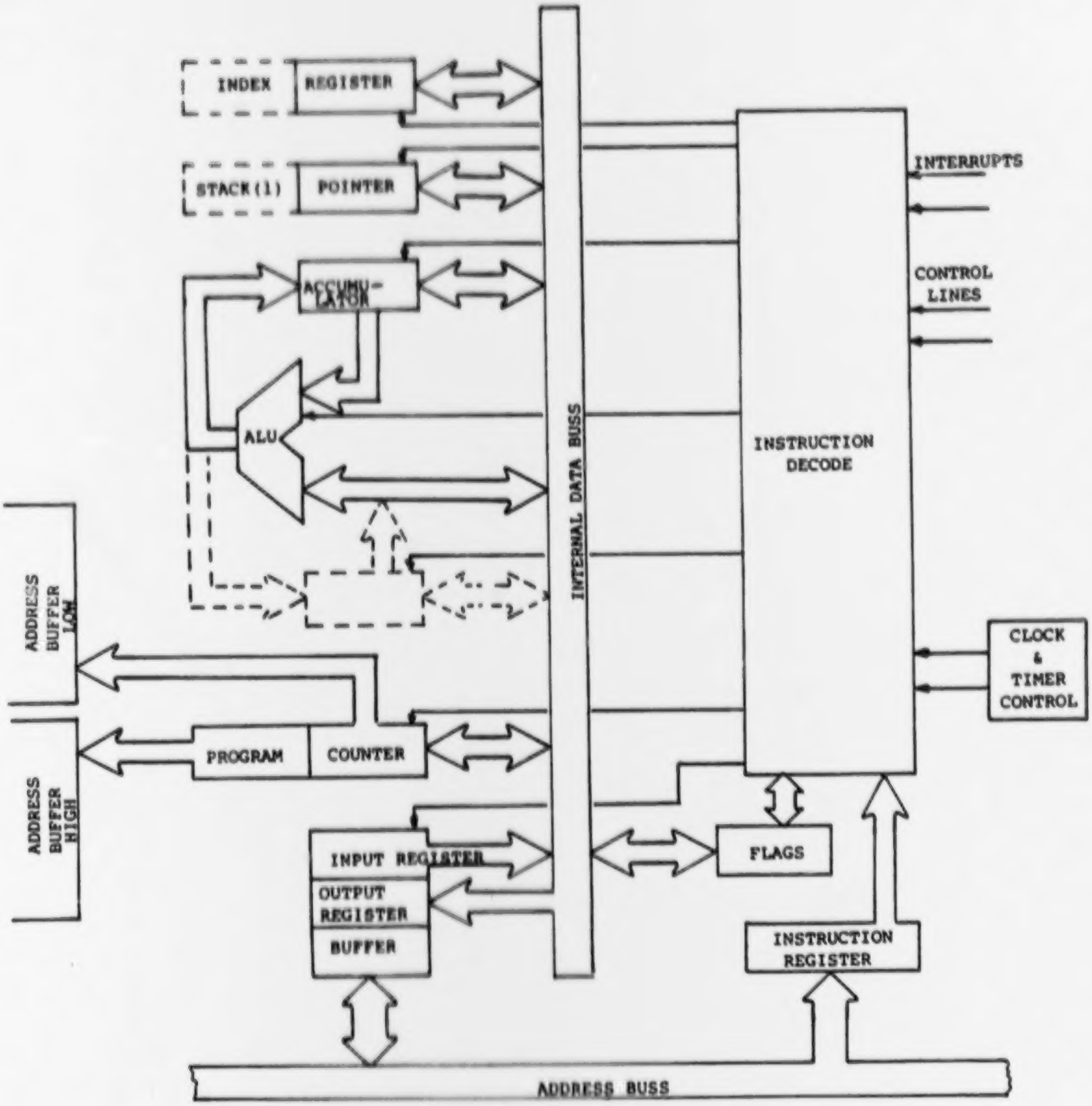
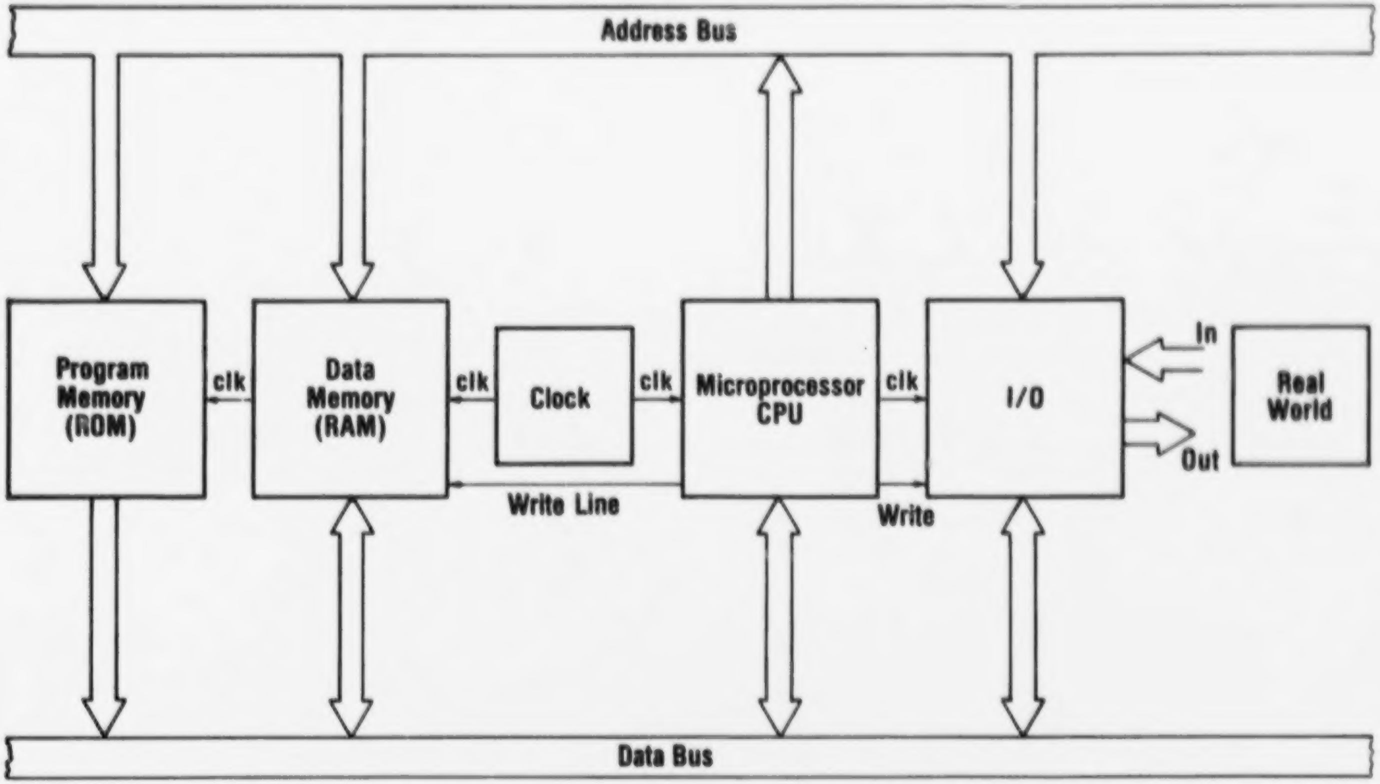
Simplified Microcomputer Block Diagram


Data Buss
In
Out
I/O Ports
Control Buss
Central Processing Unit
Control Buss
Memory (RAM and ROM)
Address Buss

Microprocessor Block Diagram


INDEX
REGISTER
STACK(1)
POINTER
ACCUMU-LATOR
ALU
INTERNAL DATA BUSS
INSTRUCTION DECODE
INTERRUPTS
CONTROL LINES
CLOCK & TIMER CONTROL
ADDRESS BUFFER LOW
ADDRESS BUFFER HIGH
PROGRAM
COUNTER
INPUT REGISTER
OUTPUT REGISTER
BUFFER
FLAGS
INSTRUCTION REGISTER
ADDRESS BUSS

System Architecture



Address Bus

Program Memory (ROM)

clk

Data Memory (RAM)

clk

Clock

clk

Microprocessor CPU

clk

I/O

In

Out

Real World

Write Line

Write

Data Bus

MICROPROCESSORS
UNIT V

JOB SHEET #1 — WRITE AND RUN A MACHINE LANGUAGE DRIVER PROGRAM TO CHECK A READ/WRITE MEMORY (RAM) LOCATION

A. Equipment and materials needed

1. Apple microcomputer as selected by instructor
2. Second microcomputer as selected by instructor
3. User's manual for each microcomputer
4. Pencil and paper

B. Procedure

(NOTE: The following procedures are for a 6502-based Apple microcomputer, but the procedure is general enough that it can be readily adapted for almost any 8-bit microprocessor.)

1. Check the user's manual for the safe procedure for turning the microcomputer ON and booting the system up.

2. Turn the microcomputer ON and boot the system up as user manual directs.

3. Make keyboard entries required to prepare the microcomputer for machine language entries.

4. Watch for the monitor signal that the microcomputer is ready for machine language entries.

   (NOTE: On an Apple microcomputer an asterisk will appear when the microcomputer is ready for machine language entries.)

5. Make the following one-line entry in hexadecimal:

   (NOTE: Remember, with the Apple, the asterisk will already be on the screen, so make only the hexadecimal entries.)

   ```
   * 300  A9  00  85  00  C5  00  D0  0B  A9  FF  85  00
   ```

6. Make the second one-line entry in hexadecimal:

   ```
   * 30C  C5  00  D0  03  4C  69  FF  20  F0  FD  E
   ```

JOB SHEET #1

7. Conclude program by typing:

   300L

8. Press the RETURN key to execute the program.

9. Check the monitor to make sure the program is displayed in assembly codes.

   (NOTE: Refer to the Driver Program that accompanies this job sheet for the machine and assembly codes and the instructions for the program.)

10. Compare the machine codes and assembly codes and what happens as the program moves through the routine of checking and comparing 0's and 1's.

11. Write down the machine codes and assembly codes and compare them.

12. Show your list of comparisons to your instructor and discuss the procedure with your instructor.

13. Turn the Apple microcomputer OFF and unplug the system.

14. Clean up area and return equipment and materials to their proper storage location.

JOB SHEET #1

6502 Driver Program

Language		
Machine	Assembly	Instruction
A9 00	LDA $00	Load the accumulator with only 0's
85 00	STA, Z $00	Store only 0's in zero page location $00
C5 00	CMP, Z $00	Compare accumulator with zero page location $00 (contents)
D0 0B	BNE $0B	Branch to error subroutine "E"
A9 FF	LDA $FF	Load the accumulator with only 1's
85 00	STA, Z 00	Store only 1's in zero page location $00
C5 00	CMP, Z 00	Compare accumulator with zero page location $00 (contents)
D0 03	BNE $03	Branch to error subroutine "E"
4C 69	JMP $FF69	Jump to monitor
FF -20	JSR $FDF0	Jump to subroutine display "E"
F0 FE		
E	$E	Data to be displayed

MICROPROCESSORS
UNIT V

JOB SHEET #2 — USE A DIGITAL VOLTMETER TO TEST SUPPLY VOLTAGES ON A MICROCOMPUTER SYSTEM BUS

A. Equipment and materials needed

1. Microcomputer as selected by instructor
2. Service manual or Computerfacts® for microcomputer
3. Digital voltmeter and operator's manual
4. Extender card for system bus (if available)
5. Pencil and paper
6. Static protection equipment (as required)

B. Procedure

1. Identify the voltage points on the system bus, and make a chart of the voltages that should be present at each point.
2. Set the DVOM for a DC function because the first measurements on the system bus will be the DC voltage.
3. Turn on the digital voltmeter and microcomputer.
4. Measure the voltages at each of the check points previously selected in step 1.
5. Record each reading in its appropriate place on your system bus voltage chart.

   (NOTE: In the event you're using an instrument that does not have automatic polarity, your lead for measuring positive voltages should be black to ground, and for measuring negative voltages, red should be to ground.)

6. Have your instructor check your work.
7. Clean up area and return equipment and materials to their proper storage location.

MICROPROCESSORS
UNIT V

JOB SHEET #3 — USE AN OSCILLOSCOPE TO CHECK A MICROCOMPUTER CLOCK SYSTEM

A. Equipment and materials needed

1. Microcomputer as selected by instructor
2. Service manual or Computerfacts™ for selected microcomputer
3. Extender card for system bus (if available)
4. Dual-trace oscilloscope and operator's manual
5. Pencil and graph paper for recording waveforms

B. Procedure for front-panel setup

1. Make sure scope is OFF.
2. Set up oscilloscope for operation.
3. Turn the oscilloscope ON and let it start warming up.
4. Have your instructor check your setup before continuing.

C. Procedure for checking clock and timing signals

1. Allow scope to fully warm up.
2. Set intensity and focus for a sharp, clear trace.
3. Set for automatic sweep.
4. Use the position knob to set the position of the channel #1 trace two divisions above center on the scope screen.
5. Use the same procedure to set the position of the channel #2 trace two divisions below center on the scope screen.

   (NOTE: This should make the two traces equal distance from the center and from the top and bottom respectively.)

6. Place the channel #1 probe to ø1 of the clock system as identified in a schematic, and then connect the ground of the #1 probe to a ground in the circuit.

JOB SHEET #3

7. Place the channel #2 probe to ϕ2 of the clock system, and although the #2 ground does not need to be connected, make sure it doesn't touch any other part of the circuit.

   (NOTE: With some leads, the ground can be detached.)

8. Turn the microcomputer ON.

9. Check for two electrical waveforms on the scope screen, and make the fine adjustments required for the vertical and horizontal controls to produce waveforms that are equal in size to approximately one vertical division on the scope.

10. Adjust the position of the horizontal control so that the leading edge of the channel #1 waveform is the starting place of the ϕ1 clock.

    (NOTE: In other words, have the ϕ1 clock coming through the zero reference on the left side of the scope.)

11. Check to verify that the preceding adjustment caused ϕ2 to go in the opposite direction of ϕ1.

    (NOTE: Remember that all microcomputer systems have both clock phases on the system bus, but there are other waveforms present on the bus also, so your instructor may have you check for other proper waveforms on the system bus.)

12. Draw a diagram of your waveform measurements, and discuss your waveforms with your instructor.

    (NOTE: One of the major objectives of this activity is not only to use the oscilloscope, but to form a good mental picture of how the oscilloscope waveform actually compares with the waveform presented in a schematic.)

13. Change the horizontal sweep frequency setting to half what it was before.

    Example: If it was 1 microsecond, change it to .5 microseconds

14. Check to see that the sweep adjustment doubled the size of the waveform on the oscilloscope screen.

    a. If it does, move on to next item.

    b. If it doesn't, check with your instructor.

15. Record your findings.

16. Change the volts per division on the vertical of channel #1 to the next lower division.

JOB SHEET #3

17. Observe the result on the screen, and also observe what happens to the channel #2 trace.

18. Change the volts per division on the vertical of channel #2 to coincide with the volts per division on channel #1.

19. Make a sketch of the waveform at this point.

20. Compare the waveform drawing from the schematic with the actual waveform as seen on the scope.

21. Have your instructor check your work, and discuss your findings with your instructor.

22. Clean up area and return equipment and materials to their proper storage location.

MICROPROCESSORS
UNIT V

JOB SHEET #1 PRACTICAL TEST — WRITE AND RUN A MACHINE LANGUAGE DRIVER PROGRAM TO CHECK A READ/WRITE MEMORY (RAM) LOCATION

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask you instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools, equipment, and materials.	______	______
2. Properly "booted" the system.	______	______
3. Properly readied the machine for machine language entries.	______	______
4. Properly entered the machine language program into the computer.	______	______
5. Properly executed the program.	______	______
6. Provided comparison of machine codes and assembly codes.	______	______
7. Properly turned off the microcomputer.	______	______
8. Observed static protection procedures.	______	______
9. Cleaned the work area.	______	______
10. Performed the tasks in a timely manner. (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout the procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Machine language program	Entered correctly			Entered incorrectly
	4	3	2	1
Machine-assembler comparison	Good comparison completed			No comparison completed
	4	3	2	1
Flow chart	Sketched correctly			Sketched correctly

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

MICROPROCESSORS
UNIT V

JOB SHEET #2 PRACTICAL TEST — USE A DIGITAL VOLTMETER TO TEST SUPPLY VOLTAGES ON A MICROCOMPUTER SYSTEM BUS

STUDENT'S NAME ________________________ DATE __________

EVALUATOR'S NAME ________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask you instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools, equipment, and materials.	______	______
2. Properly identified and charted voltages on system bus.	______	______
3. Properly readied digital voltmeter and microcomputer.	______	______
4. Properly recorded measurements.	______	______
5. Cleaned the work area.	______	______
6. Observed static protection procedures.	______	______
7. Performed the tasks in a timely manner. (___hrs. ___min. ___sec.)	______	______
8. Practiced safety rules throughout the procedure.	______	______
9. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:	4	3	2	1
Constructed voltage chart	Correct voltages Organized Readable			Incorrect voltages Disorganized Not readable
	4	3	2	1
Obtained voltage measurements	Correct measurements			Incorrect measurements
	4	3	2	1
Identified measured points	Correct points			Incorrect points

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

MICROPROCESSORS
UNIT V

JOB SHEET #3 PRACTICAL TEST — USE AN OSCILLOSCOPE TO CHECK A MICROCOMPUTER CLOCK SYSTEM

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask you instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools, equipment, and materials.	______	______
2. Properly set up oscilloscope.	______	______
3. Located proper test points.	______	______
4. Properly connected oscilloscope to test points.	______	______
5. Proper waveforms displayed on oscilloscope.	______	______
6. Cleaned the work area.	______	______
7. Performed the tasks in a timely manner (___hrs. ___min. ___sec.)	______	______
8. Practiced safety rules throughout the procedure.	______	______
9. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Clock Waveform	Correct waveform			Incorrect waveform

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

MICROPROCESSORS
UNIT V

NAME ______________________ SCORE ____________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. A binary word that the microprocessor uses as an address to determine the location of a memory or I/O word

_____b. A binary word that the microprocessor manipulates internally by moving, storing, or performing an operation on to accomplish a desired result

_____c. Increasing the contents of an address or register by one

_____d. Decreasing the contents of an address or register by one

_____e. The timing of a bit or binary word so that it coincides with a precisely timed signal source

_____f. The condition in which the timing of a bit or binary word does not coincide with the signal source used in the system

_____g. The point where two components connect within a system and/or the device used to make the connection

_____h. A communications exchange accomplished with software

_____i. The arithmetic logic unit, registers, and timing and decoding circuitry usually contained in a single integrated circuit that control computer activity

_____j. A computer system whose processing unit is a microprocessor that contains memory and input-output facilities

_____k. Any device such as a disk drive, printer, modem, or video display added to a microcomputer to provide increased capacity for handling, storing, or presenting data

1. Address word
2. Asynchronous
3. Byte
4. Data word
5. Decrementing
6. Handshaking
7. Incrementing
8. Interface
9. Microcomputer
10. Microprocessor
11. Mnemonics
12. Peripheral
13. Protocol
14. Synchronous

TEST

______l. A string of binary digits, usually eight; operated on as a basic unit by a digital computer

______m. Acronyms chosen to aid the programmer or technician

______n. An exchange of predetermined signals when a connection is made between two data-set devices

2. Complete the following statements concerning sections of a microcomputer and their functions by inserting the word(s) that best complete(s) each statement.

   a. The ____________ ____________ is the heart of the microcomputer system and contains the arithmetic logic unit (ALU), the control circuitry, some registers, and a program/address counter.

   b. The ____________ section usually contains RAM and ROM, and magnetic memory used for temporary or permanent storage of binary information.

   c. The ____________-____________ section contains circuitry to provide the interface to the peripheral devices outside the computer.

   d. ____________ are a system of wires or printed circuits used to connect the CPU to the remainder of the system.

   e. ____________ are internal devices where stored information is manipulated as a group of bits.

3. Match the sections of the CPU on the right with their correct functions.

______a. Receives binary instructions from the data bus, decodes them, and processes clock timing and interrupt signals

______b. Contains the ALU, the program counter, the index and flag registers, the accumulators, and the stack pointer

______c. Performs arithmetic and logic functions, sends information to the accumulator, and initiates the output to the flag register

______d. Stores quantities to be operated by the ALU and receives the results of the arithmetic operation performed by the ALU

______e. Controls the step-by-step progress as the CPU executes a program

1. Arithmetic logic unit
2. Accumulator
3. Program counter
4. Index register
5. Stack pointer
6. Flag register
7. Register section
8. Control section

TEST

_____f. Performs the task of indexing in one direction or the other through memory to help accomplish a repetitive function and is unique in that when instructed it will add (increment) or subtract (decrement) from its contents by 1

_____g. Keeps track of where things are when stacking in memory occurs, and points the programmer to the location of where information is stored (stacked)

_____h. Contains bits of information that indicate the status of the microprocessor at the end of the last instruction that was executed

4. List three ways information flows in a microprocessor.

a. ______________________________

b. ______________________________

c. ______________________________

5. Match the memory devices on the right with their functions.

_____a. Is a nonvolatile type (contents do not change and normally cannot be altered) in integrated circuit form which has been programmed to control the basic operations of the system and such other decoding functions as reading the keyboard and controlling video information to display; retains its contents when power is turned off

_____b. Is a ROM whose contents may be altered quickly by electrical erasure

_____c. May be erased by ultraviolet light and reprogrammed by the user; retains its contents when power is turned off

_____d. Is a read and write memory that may be changed at any time but loses its contents when power is turned off

1. ROM
2. RAM
3. EPROM
4. EAPROM

TEST

6. Complete the following statements concerning busses and their functions by circling the word that best completes each statement.

   a. Busses carry multiple signals from one part of a circuit or system to another part in such a way that the arrival of all bits of information are timed to (**glitch, coincide**).

   b. Most busses in microcomputers are parallel (**synchronous, asynchronous**) busses to indicate the element of timing essential to their functions.

   c. Microcomputers contain a (**system bus, address bus**) such as the S-100 or IEEE 488, into which expansion and interface board or cards that enhance or modify the systems capabilities may be placed.

   d. Data busses, address busses, and control busses are contained within the microcomputer to transfer and control (**data, diskettes**).

7. Complete the following statements concerning the characteristics of the data bus by inserting the word(s) that best complete(s) each statement.

   a. The ____________ bus carries information in 8-bit binary words to and from the microprocessor.

   b. The 8-bit binary word is synchronized by the system ____________ and is bidirectional.

   c. The binary word on the data bus may contain an ____________, ____________, or ____________ information.

   d. The data bus may be a ____________ cable or PC board pathway and consists of parallel conductors that simultaneously carry 8 binary 1's or 0's or combinations of the two binary digits.

8. Complete the following statements concerning the characteristics of the address bus by inserting the word(s) that best completes each statement.

   a. The address bus carries addresses generated by the ____________ to a designated device such as RAM, ROM, or I/O device.

   b. Information carried on the ____________ bus may also identify the location within RAM, ROM, or I/O from which the microprocessor may receive information from or send information to.

   c. The ____________ bus may be a multiconductor cable or PC board that consists of 16 parallel lines that simultaneously carries a combination of 16 binary 1's and 0's.

TEST

9. Select true statements concerning the characteristics of the control bus by placing an "X" in the blanks preceding the true statements.

_____a. Specialized control bus functions vary from system to system.

_____b. The control bus controls the timing and direction of information.

_____c. Control signals are not as synchronized along the parallel lines as the data and address signals are.

_____d. The control bus usually carries clock pulses, read/write signals, and interrupt signals.

10. Complete the following statements concerning the clock and clock timing characteristics by inserting the word(s) that best completes each statement.

a. ____________ of a microprocessor microcomputer system is accomplished with a clock circuit on the microprocessor chip or with a separate clock circuit.

b. The ____________ waveform is usually a two-phase nonoverlapping type with two signals at the same frequency by starting at different times.

c. When one waveform is high the other is low with the waveforms identified as phase ____________ (high) and phase ____________ (low).

d. The clock provides ____________ signals to all parts of the system and does not have to be addressed.

e. The ____________ controls the system busses and the ____________ controls timing to all of the system.

f. The high-speed timing cycle may be manipulated by an ____________ signal from the operator of the computer or from an external peripheral device.

11. Describe the functions of interrupts.

____

____

____

____

TEST

12. Arrange in order the steps in a microcomputer operating cycle by indicating the first step as 1, the second step as 2, and so on for each step.

_____a. In the CPU, the decoder sets up the appropriate registers in response to the instruction that was placed in the instruction register.

_____b. After the registers are set up, one of two operations normally occur:

1) The CPU may execute the program directly if no further data is required

2) The CPU may require that the program counter send another address out on the system address bus to retrieve data from another memory address which may be required to complete the instruction cycle

_____c. The address bus selects the contents of the memory specified and places the binary instruction that it finds onto the data bus.

_____d. The data bus carries its data to the instruction register of the CPU.

_____e. Before a program may be executed, the program counter must be set to a memory location that begins the program.

_____f. The CPU places the contents of the program counter on the address bus, then the program counter proceeds to the next sequential memory location where it stops until it receives instruction from the CPU decoder section.

13. Complete the following statements concerning characteristics of machine language by inserting the word(s) that best completes each statement.

a. Machine language requires that the computer operator specify actual memory ____________ in the computer and machine codes that are understood by the computer control section.

b. Machine language requires data necessary for the operation at the level the computer can understand, which is usually ____________ or ____________.

c. Machine language requires that an operator know the codes and the addressing modes of the instructions for a specific ____________ chip because each chip has a different set of codes.

d. Most system troubleshooting routines are written in ____________ language.

e. It usually takes a longer time to write a program in machine language than in any other language, but the resulting program executes the ____________.

TEST

14. Complete the following statements concerning the characteristics of assembler language by inserting the word(s) that best completes each statement.

    a. Assembler language replaces machine codes with __________.

    b. __________ are usually three or four-letter codes that may be abbreviations for the operation to be performed.

    c. Addressing in __________ language is done by "labeling" rather than giving specific machine addresses.

    d. After a program is written in assembler language, the __________ and labels must be run through a program called an "assembler".

    e. The assembler program will generate the __________ code which will operate the computer.

    f. Assembler language programming can be accomplished __________ than programming with machine language.

15. Name two standards of communications for digital information.

    a. ______________________________

    b. ______________________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

16. Demonstrate the ability to:

    a. Write and run a machine language driver program to check a read/write memory (RAM) location. (Job Sheet #1)

    b. Use a digital voltmeter to test supply voltages on a microcomputer system bus. (Job Sheet #2)

    c. Use an oscilloscope to check a microcomputer clock system. (Job Sheet #3)

MICROPROCESSORS
UNIT V

ANSWERS TO TEST

1. a. 1
   b. 4
   c. 7
   d. 5
   e. 14
   f. 2
   g. 8
   h. 13
   i. 10
   j. 9
   k. 12
   l. 3
   m. 11
   n. 6

2. a. Central processing unit
   b. Memory
   c. Input-output
   d. Busses
   e. Registers

3. a. 8
   b. 7
   c. 1
   d. 2
   e. 3
   f. 4
   g. 5
   h. 6

4. a. As an ADDRESS WORD
   b. As a DATA WORD
   c. As CONTROL information

5. a. 1
   b. 4
   c. 2
   d. 3

6. a. Coincide
   b. Synchronous
   c. System bus
   d. Data

7. a. Data
   b. Clock
   c. Instruction, data, address
   d. Multiconductor

ANSWERS TO TEST

8. a. Microprocessor
   b. Address
   c. Address

9. a, b, c, d

10. a. Timing
    b. Clock
    c. One, two
    d. Timing
    e. CPU
    f. Interrupt

11. The interrupt is a signal from a piece of equipment requesting service. An interrupt will cause a microprocessor to stop what it is doing and perform some other task that it was preprogrammed to do.

12. a. 5
    b. 6
    c. 3
    d. 4
    e. 1
    f. 2

13. a. Addresses
    b. Binary, hexadecimal
    c. Microprocessor
    d. Machine
    e. Fastest

14. a. Mnemonics
    b. Mnemonics
    c. Assembly
    d. Mnemonics
    e. Machine
    f. Much faster

15. a. RS-232C
    b. Centronics

16. Performance skills evaluated according to industry standards and to the satisfaction of the instructor.

MODULATION/DEMODULATION TECHNIQUES
UNIT VI

UNIT OBJECTIVE

After completion of this unit, the student should be able to demonstrate the ability to analyze modulation and demodulation techniques in AM and FM systems. Competencies will be demonstrated by completing the assignment sheets, job sheet, and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to modulation/demodulation with their correct definitions.
2. Complete statements concerning basic principles of the modulation process.
3. Select true statements concerning basic requirements of the demodulation process.
4. Complete statements concerning the characteristics of amplitude modulation.
5. Complete statements concerning the characteristics of single-sideband modulation.
6. Match types of AM modulators with their schematic diagrams.
7. Match types of AM demodulators with their schematic diagrams.
8. Select true statements concerning characteristics of frequency modulation.
9. Complete statements concerning frequency deviation in FM systems.

OBJECTIVE SHEET

10. Write the formula for determining modulation index.
11. Distinguish between types of FM modulators.
12. Match types of FM demodulators with their schematic diagrams.
13. Complete statements concerning characteristics of phase modulation.
14. Calculate percent of modulation. (Assignment Sheet #1)
15. Calculate modulation index. (Assignment Sheet #2)
16. Demonstrate the ability to construct and analyze a diode detector. (Job Sheet #1)

MODULATION/DEMODULATION TECHNIQUES
UNIT VI

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheet.

H. Discuss and demonstrate the procedures outlined in the job sheet.

I. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate modulation and demodulation techniques used in commercial systems.
2. Analyze technical data sheets on integrated circuit modulators and demodulators.
3. Show films or tapes on modulation and demodulation.
4. Demonstrate the use of a spectrum analyzer to observe sideband frequencies in AM and FM.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN WRITING THIS UNIT

A. *Electronic Communications*. Benton Harbor, MI: Heath Company, 1981.

B. Dugan, Frank R. *Linear Integrated Circuits for Technicians*. North Scituate, Mass: Breton Publishers/Wadsworth Inc., 1984.

C. Hardy, James K. *Electronic Communications Technology*. Englewood Cliffs, NJ: Prentice-Hall, 1986.

D. Kennedy, George. *Electronic Communication Systems*. Third Edition. New York: McGraw-Hill Book Company, 1985.

E. Schrader, Robert L. *Electronic Communication*. Fifth Edition. New York: McGraw-Hill Book Company, 1985.

MODULATION/DEMODULATION TECHNIQUES
UNIT VI

INFORMATION SHEET

I. **Terms and definitions**

   A. Amplitude modulation — Modulation in which the amplitude of the carrier is the characteristic that is varied

   B. Carrier — A continuous wave radio frequency to which intelligence may be added by the process of modulation

   C. Demodulation — The process of removing the modulation signal from the associated carrier waveform

   D. Frequency modulation — Modulation in which the frequency of the carrier is the characteristic that is varied

   E. Heterodyne — Process of combining two signals of different frequencies to obtain another frequency different from the original

   F. High level modulation — Method of mixing the audio and RF in the plate/collector circuit of the last stage RF amplifier

   G. Intelligence signal — Electronic signal that conveys information such as voice, music, or data

   H. Low level modulation — Method of mixing the audio and RF at a point in the transmitter prior to the plate/collector of the last stage RF amplifier

   I. Modulation — The process by which the alteration or modification of the characteristics of one waveform or signal is accomplished in accordance with the characteristic of another waveform called a modulation signal

   J. Sideband frequencies — Frequencies above or below the carrier frequency as a result of modulation

II. **Basic principles of the modulation process** (Transparency 1)

   A. Modulation is a process through which the characteristics of a high-frequency carrier waveform is varied in accordance with the waveform of a superimposed intelligence signal such as music or voice.

   B. Three characteristics of a sine wave carrier which may be varied are

      1. Amplitude

      2. Frequency

      3. Phase

INFORMATION SHEET

III. **Basic requirements of the demodulation process**

A. Demodulator input circuit must be sensitive to the modulation characteristics.

B. Nonlinearity must be present.

C. An RF carrier signal must be present at the input of the demodulator to heterodyne with the sideband signals to reproduce the original intelligence signal.

D. Filtering is required at the output of the demodulator to select the desired intelligence signal and reject the unwanted RF frequencies.

IV. **Characteristics of amplitude modulation**

A. Amplitude modulation exists when the amplitude of a carrier waveform is varied with a modulating frequency and voltage while the frequency of the carrier is held constant.

B. A modulated carrier contains the carrier frequency plus two new sideband frequencies.

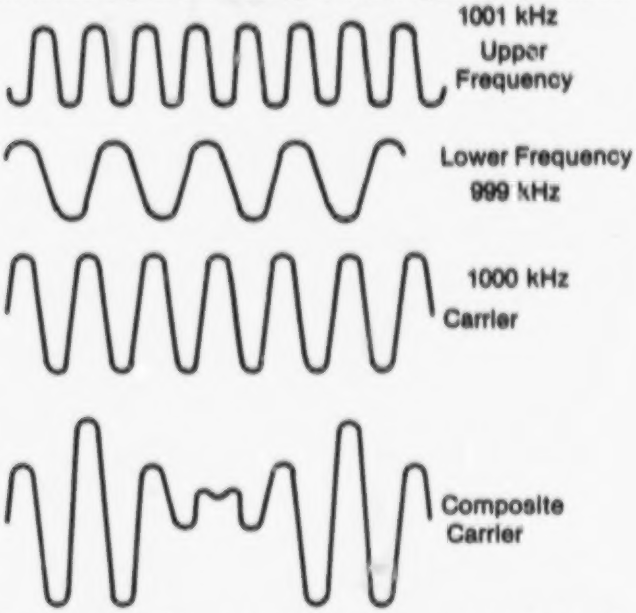
1. The upper sideband (USB) is equal to the carrier frequency plus the modulating frequency.

2. The lower sideband (LSB) is equal to the carrier frequency minus the modulating frequency.

C. The amplitude of the modulated carrier is the algebraic sum of the instantaneous amplitudes of the unmodulated carrier and the upper frequency and the lower frequency signals.

INFORMATION SHEET

D. The bandwidth of the amplitude modulated signal refers to the space the transmitted signal will occupy in the frequency spectrum.



E. The percentage of modulation may be calculated by the formula

$$\%\ \text{modulation} = \frac{\text{Emax} - \text{Emin}}{\text{Emax} + \text{Emin}} \times 100$$

F. The total power radiated in an amplitude modulated carrier wave is equal to the sum of the power contained in the separate components of the modulated wave.

P (total) = P (carrier) + P (USB) + P (LSB)

G. When a carrier is modulated at 100%

1. Total sideband power is one-half the carrier power.
2. The carrier contains two-thirds of the total power.
3. Total sideband power is one-third of the total transmitted power.
4. Sideband power is distributed equally in two sidebands.
5. Each sideband contains one-sixth of the total power.

H. Overmodulation produces severe distortion which produces new modulating frequencies causing a considerable increase in bandwidth of the transmitted signal.

INFORMATION SHEET

V. **Characteristics of single-sideband modulation**

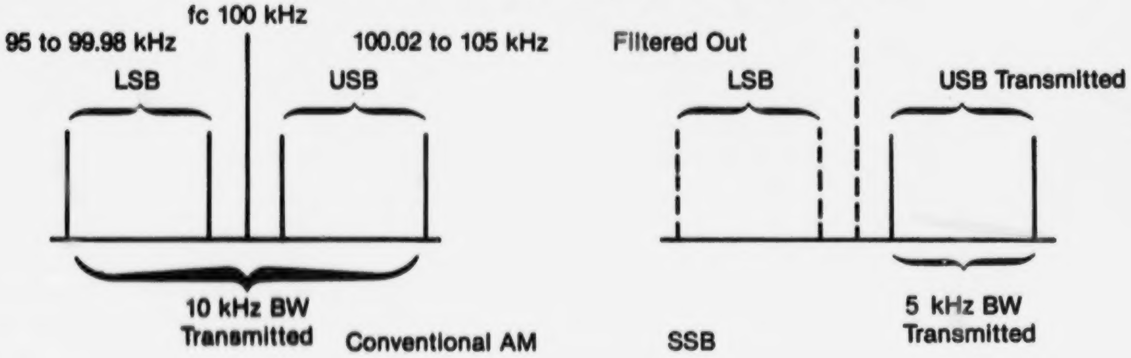
A. Single-sideband operation involves the transmission of only one sideband.

1. A carrier is modulated with an intelligence signal.
2. The carrier is suppressed.
3. One of the two sidebands is eliminated.

B. An intelligence signal, a carrier signal, a balanced modulator circuit, and a sideband filter is needed to generate a single-sideband signal.

1. Generation of the single-sideband signal usually occurs at a lower power stage in the transmitter.
2. The bandwidth of a single-sideband signal is approximately one-half the bandwidth of the conventional AM signal.

Carrier = 100 kHz Modulation = 200 Hz to 5 kHz


fc 100 kHz
95 to 99.98 kHz
100.02 to 105 kHz
LSB
USB
10 kHz BW Transmitted
Conventional AM
Filtered Out
LSB
USB Transmitted
5 kHz BW Transmitted
SSB

VI. **Types of AM modulators**

A. The diode modulator is a very simple amplitude-modulator circuit. (Transparency 2)

1. Linear mixing of the carrier and modulating signals is accomplished by a simple resistive network at the input.
2. Nonlinear mixing of the combined signals is accomplished as the signals are rectified by the diode.
3. The bandpass filter allows the carrier and its sidebands to pass while illuminating the original modulating signal and all unwanted harmonics.

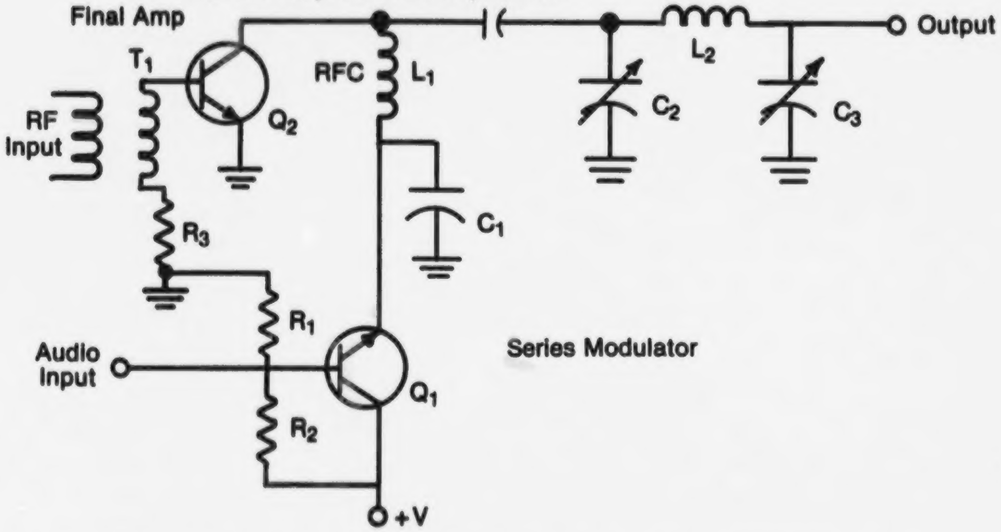
INFORMATION SHEET

B. A common AM modulator is the collector modulator.

1. It is a high-level modulator.
2. The transistor operates class-C.
3. The modulating signal is applied to the collector in series with DC supply voltage.

C. A series modulator eliminates the modulation transformer by using a transistor to inject the modulating frequency.

1. There is less frequency distortion than with the collector modulator.
2. This is a very inefficient operation.

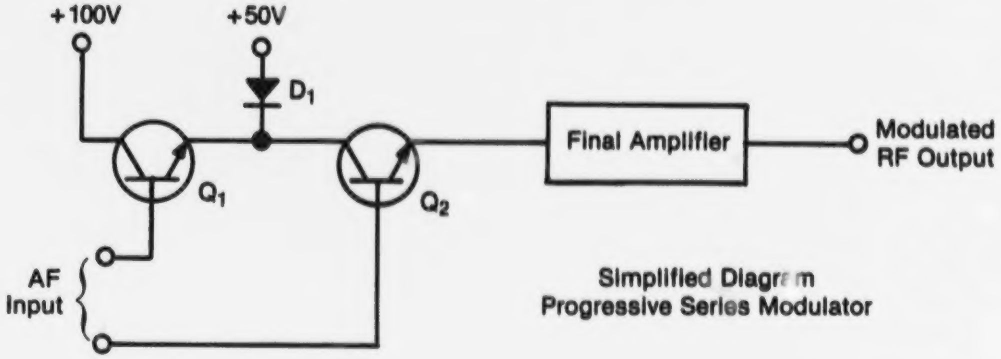

Final Amp
T1
RF Input
Q2
RFC
L1
C1
C2
L2
C3
Output
R3
R1
R2
Audio Input
Q1
+V
Series Modulator

D. A progressive series modulator is an improved series modulation circuit.

1. It has greatly improved efficiency.
2. It maintains improved frequency characteristics compared to collector modulator.

INFORMATION SHEET

3. Very little power is lost under carrier only conditions (0% modulation).


+100V
+50V
D$_1$
Q$_1$
Q$_2$
Final Amplifier
Modulated RF Output
AF Input

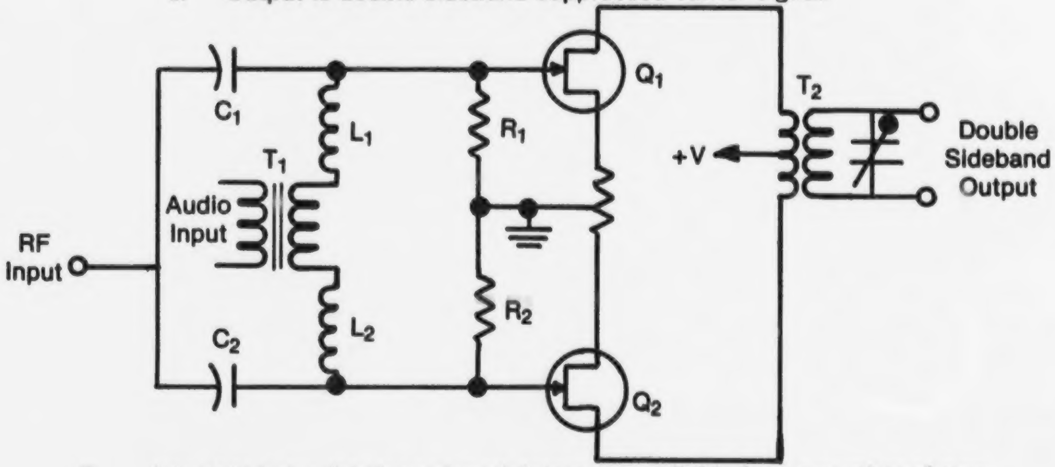
Simplified Diagram
Progressive Series Modulator

E. A relatively simple balanced modulator is the twin-FET balanced modulator.

1. The modulating signal is applied to gates of FET's with 180 degree phase difference.

2. The carrier is cancelled across primary winding of output transformer.

3. Output is double sideband suppressed carrier signal.

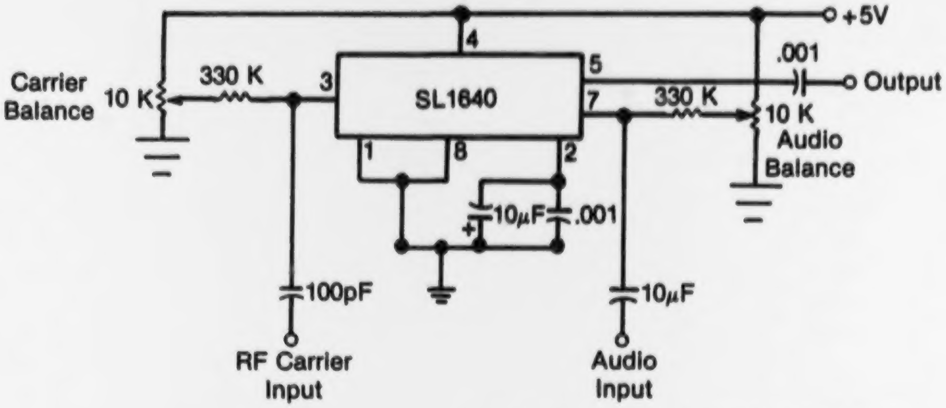

C$_1$
L$_1$
R$_1$
Q$_1$
T$_2$
+V
Double Sideband Output
T$_1$
Audio Input
RF Input
R$_2$
L$_2$
C$_2$
Q$_2$

F. Integrated circuit balanced modulators are available from a number of manufacturers.

1. These usually employ differential amplifiers.

INFORMATION SHEET

2. They have relatively simple and compact external circuitry.


+5V
4
.001
Output
Carrier Balance
10 K
330 K
3
SL1640
5
7
330 K
10 K Audio Balance
1
8
2
10μF
.001
100pF
10μF
RF Carrier Input
Audio Input

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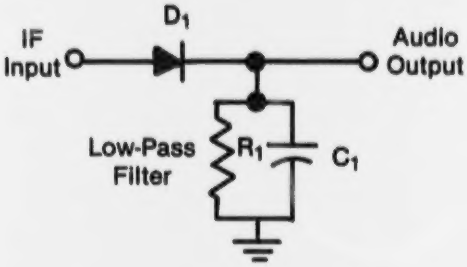
VII. **Types of AM demodulators**

A. The diode detector is the most popular of the AM demodulators.


D1
IF Input
Audio Output
Low-Pass Filter
R1
C1

1. Diode mixes RF signal consisting of the carrier, the upper sideband, and the lower sideband.

2. Low pass filter removes the high frequency components and passes the low frequency intelligence signal.

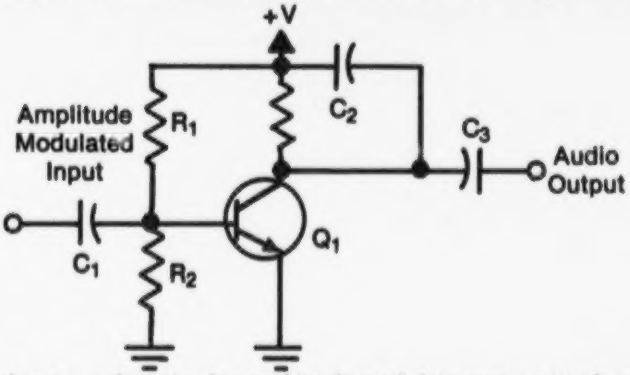
B. A transistor detector provides for detection of the signal and achieves additional signal gain.

1. Transistor is operated class B

2. Rectification and amplification provided by the transistor

INFORMATION SHEET

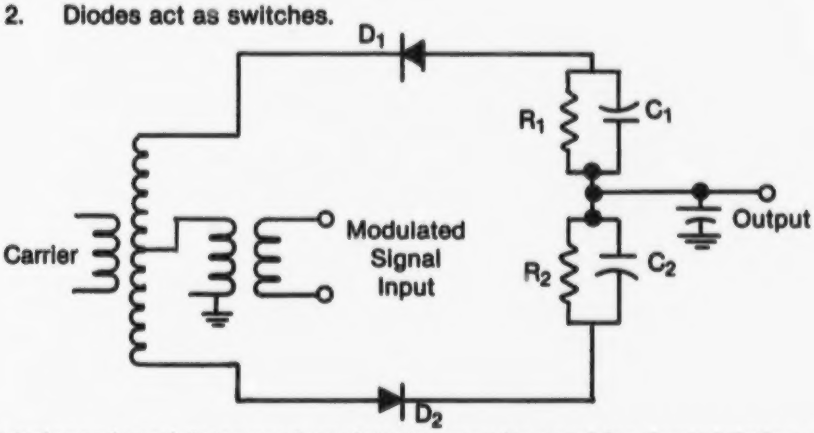
3. Capacitor in collector circuit filters out RF components


+V
Amplitude Modulated Input
R₁
C₂
C₃
Audio Output
C₁
R₂
Q₁

C. A synchronous detector is used to demodulate suppressed carrier AM signals.

1. Elaborate circuitry is required to recreate the carrier before detection can occur.

2. Diodes act as switches.


D₁
R₁
C₁
Output
Carrier
Modulated Signal Input
R₂
C₂
D₂

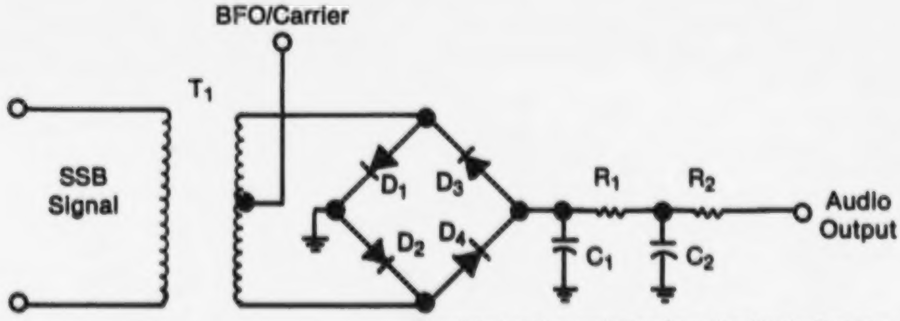
D. A balanced modulator product detector may be used for demodulation of SSB signals.

1. It is sensitive to both frequency and amplitude variations.

2. It performs as nonlinear mixer.

INFORMATION SHEET

3. Low pass filter network removes RF component.


BFO/Carrier
T1
SSB Signal
D1
D3
D2
D4
R1
R2
C1
C2
Audio Output

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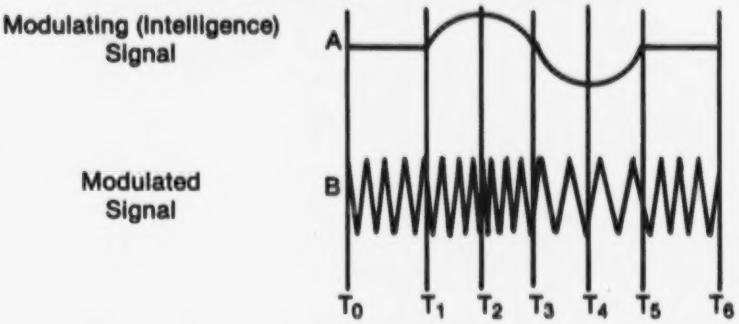
VIII. **Characteristics of frequency modulation**

A. Frequency modulation is angle modulation of a sinusoidal carrier.

1. Instantaneous frequency of the modulated wave differs from the carrier frequency by an amount proportional to the instantaneous amplitude of the modulating frequency.

2. The modulating signal is the intelligence signal.


Modulating (Intelligence) Signal
A
Modulated Signal
B
T0
T1
T2
T3
T4
T5
T6

B. The unmodulated carrier frequency in FM is called the center frequency.

C. The center frequency is present only when there is no modulation applied.

D. When a modulating frequency is present with a positive amplitude the frequency of the modulated waveform is higher than the center frequency.

E. When a modulating frequency is present with a negative amplitude the frequency of the modulated waveform is lower than the center frequency.

INFORMATION SHEET

IX. **Frequency deviation in FM systems**

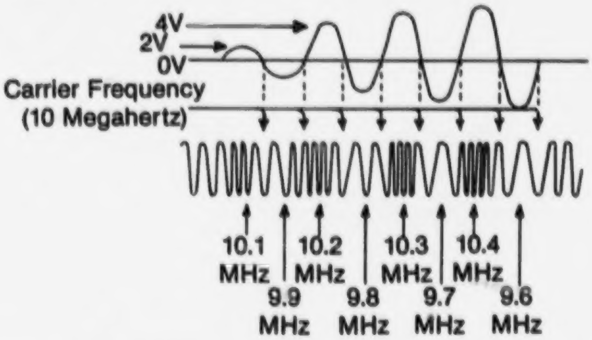
A. The difference between the instantaneous frequency of the modulated wave and the carrier frequency is called the frequency deviation.

1. The oscillator oscillates at the center frequency when no modulating signal is applied.

2. An intelligence signal from the modulator will cause the oscillator to change frequency above and below the center frequency.

3. Maximum deviation will occur at the voltage peak of the modulating signal.

B. The amount of deviation of the oscillator is determined by the amplitude of the modulating signal.



C. Maximum deviation occurs at the peak amplitude of the modulating signal.

D. The frequency of the modulating signal determines the rate of deviation of the oscillator above and below the center frequency.

X. **Determining modulation index** (Transparency 3)

A. An FM waveform contains an infinite number of sidebands.

B. The number of significant sidebands determine the bandwidth of the transmitted signal.

C. The number of significant sidebands is determined by the modulation index (MI).

D. Modulation index (MI) is a ratio of the frequency deviation to the modulating signal frequency causing the deviation.

INFORMATION SHEET

E. A formula for determining modulation index is:

$$MI = \frac{fd}{fm}$$

fd = frequency deviation

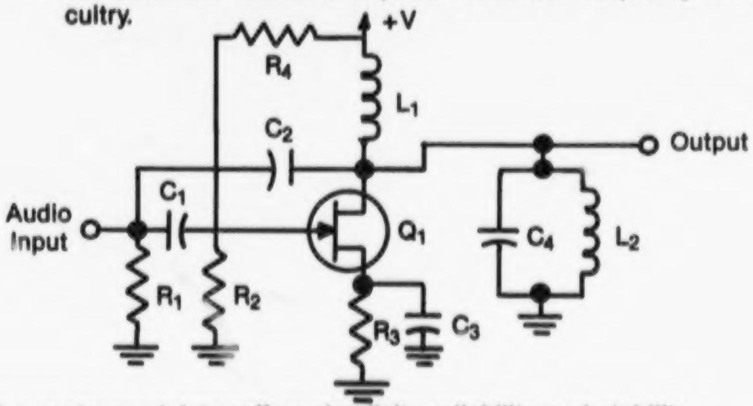
fm = frequency of the modulating signal

MI = Modulation index

XI. **Types of FM modulators**

A. A reactance modulator incorporates the direct modulation process where the master oscillator frequency is varied in accordance with the modulating signal.

1. FET is biased so as to appear as capacitive or inductive reactance to master oscillator.
2. As reactance varies, the master oscillator frequency varies.
3. A disadvantage is that it cannot be used with a crystal controlled oscillator and therefore requires additional frequency control circuitry.

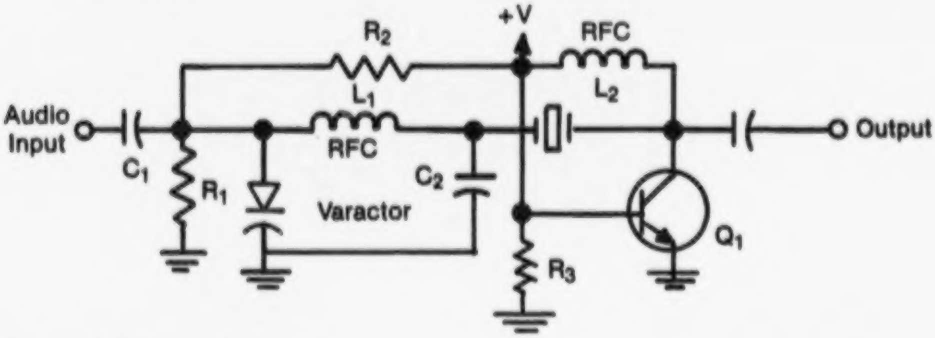


B. A varactor modulator offers simplicity, reliability, and stability.

1. Crystal oscillator provides stability.
2. Varactor diode is reversed biased to establish nominal capacitance value for oscillators center frequency.
3. When modulating signal is applied, the signal adds and subtracts from varactor bias changing the varactors capacitance which causes a change in oscillator frequency.

INFORMATION SHEET

4. Rate of deviation from center frequency is same as the modulating signal.



XII. **Types of FM demodulators**

A. The slope detector is the simplest FM detector.

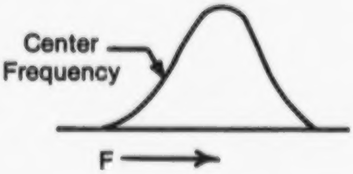
1. It uses the slope of the response curve on tuned resonant circuits.

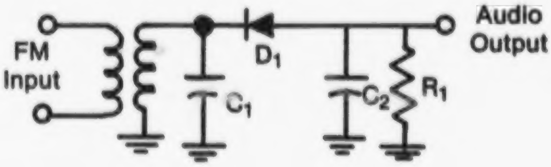
2. Center frequency of carrier is positioned approximately half way up the side of the response curve.

3. When carrier signal is above the center frequency, a higher amplitude signal is applied to the diode.

4. When the carrier signal is below the center frequency, a lower amplitude signal is applied to the diode.

5. The diode detects the variations in amplitude as in an AM detector. For FM detectors it must be preceded by a limiter.





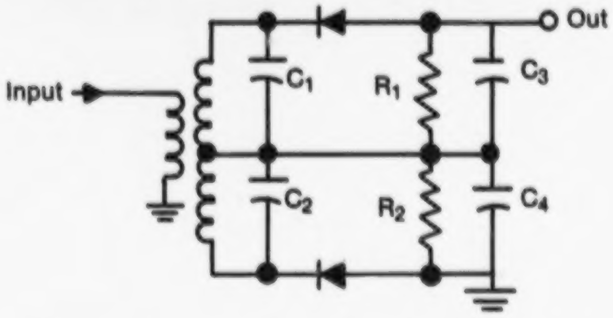
B. A double tuned detector uses a center tapped transformer with two capacitors to form two tuned circuits.

1. Upper half of transformer and associated capacitor is tuned to resonate slightly above the center frequency.

INFORMATION SHEET

2. Lower half of transformer and associated capacitor is tuned to resonate slightly below the center frequency.

3. When frequency is applied above or below center frequency, one of the diodes conducts more than the other producing a detected output that corresponds to the intelligence signal.



C. The Foster-Seeley discriminator is a more popular FM detector.

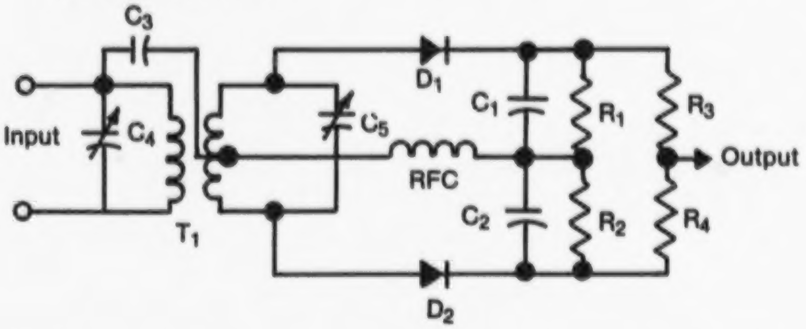
1. Both diodes conduct equally at the center frequency.

2. D1 conducts harder above the center frequency.

3. D2 conducts harder below the center frequency.

4. Resultant output is detected intelligence signal.

5. Less sensitive to amplitude variations than the slope detector, but still needs a limiter.



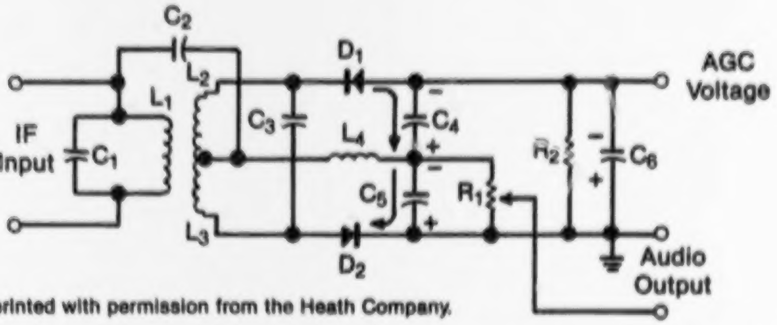
D. The ratio detector is an improved circuit that is one of the most popular of the FM detectors.

1. Diodes are in series across the entire secondary of the transformer.

2. Diodes alternately conduct harder as the frequency of the signal swings above and below the center frequency.

INFORMATION SHEET

3. The circuit is relatively insensitive to noise.


C2
L2
L1
IF
Input
C1
L3
C3
D1
L4
C4
C5
D2
R1
R2
C6
AGC
Voltage
Audio
Output

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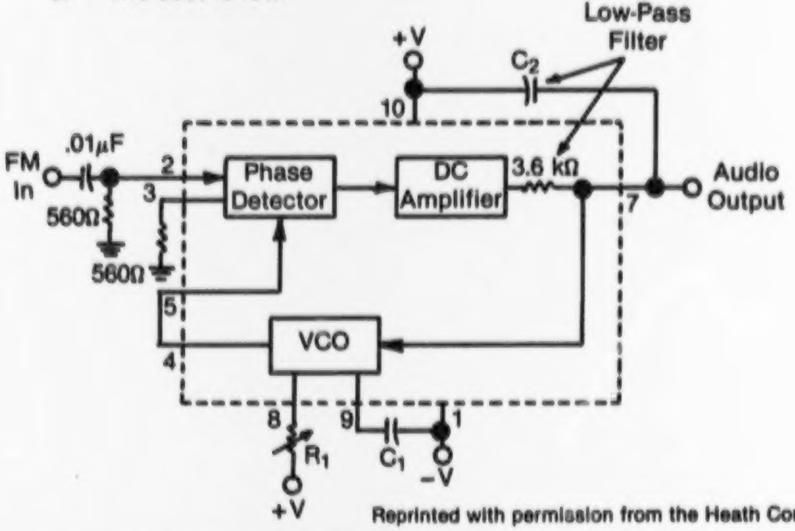
E. The phase-locked loop FM demodulator is available as an integrated circuit.

1. It has simplified tuning requirements.

2. It offers excellent performance.

3. The cost is low.


Low-Pass
Filter
+V
C2
10
FM
In
.01μF
2
3
560Ω
560Ω
Phase
Detector
DC
Amplifier
3.6 kΩ
7
Audio
Output
5
4
VCO
8
R1
+V
9
C1
1
-V

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XIII. Characteristics of phase modulation

(NOTE: Phase modulation and frequency modulation are sometimes combined into one category called angle modulation due to similarities in circuitry and performance.)

A. A phase-modulated waveform is produced by shifting the phase of the carrier with respect to the modulating voltage while maintaining the amplitude of the carrier constant.

INFORMATION SHEET

B. The rate at which a phase-modulated wave shifts from one phase value to another is proportional to the frequency of the modulating voltage.

C. The number of degrees through which the phase of the carrier is shifted is proportional to the amplitude of the modulating voltage.

D. The amplitude of the modulating signal determines the number of significant sidebands.

E. Sidebands are spaced on either side of the carrier by an amount equal to the modulating signal frequency.

F. The sidebands contain the intelligence signal.

G. Increasing the amplitude or frequency of the modulating signal increases the bandwidth of the transmitted signal.

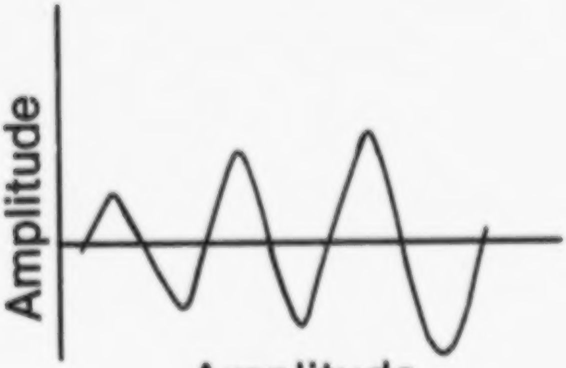
H. Indirect modulation techniques are employed in phase modulation providing for good frequency stability.

   1. Output is both phase and amplitude modulated.

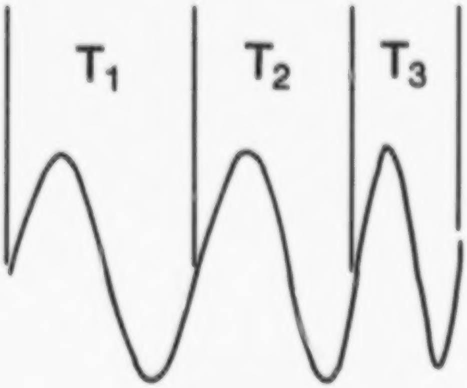
   2. Output is fed to class C amplifiers which remove amplitude variations.

I. Phase modulation is used mostly for narrow band, two-way FM communications.

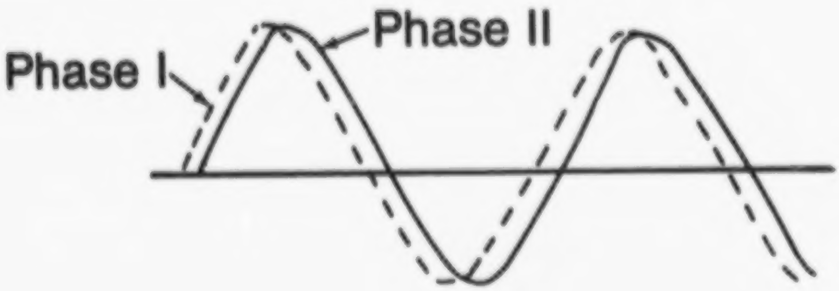
Modulation



Amplitude

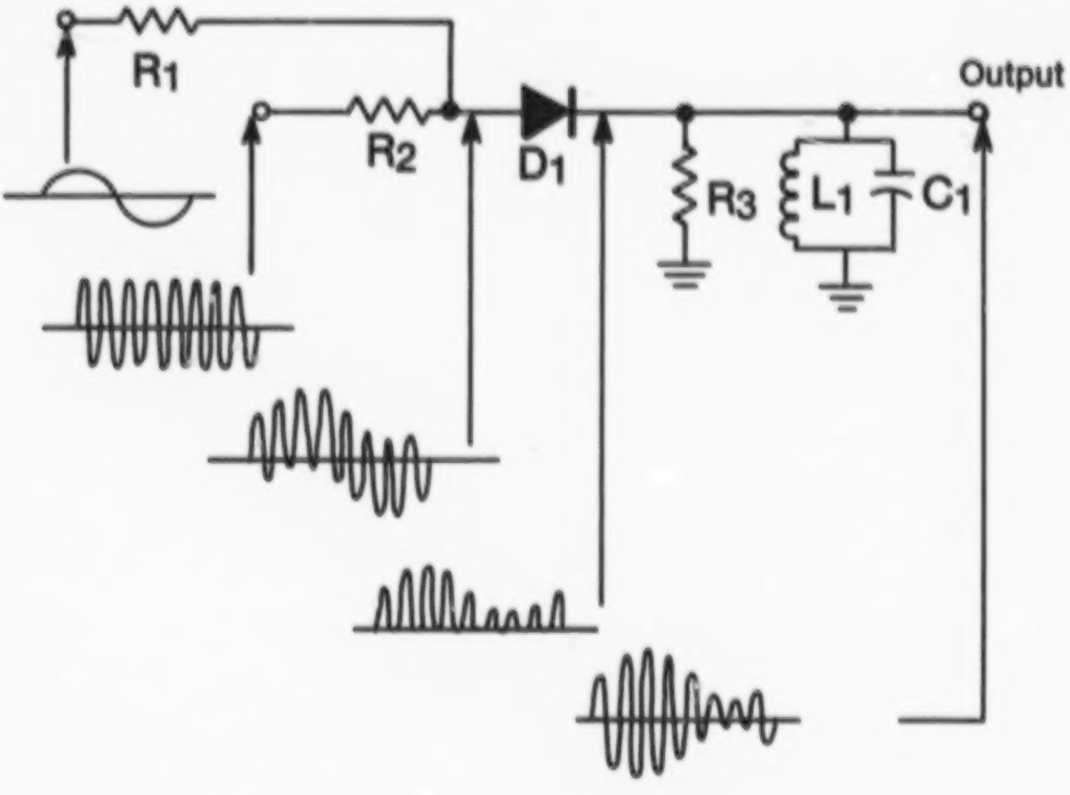


Frequency


Phase I
Phase II

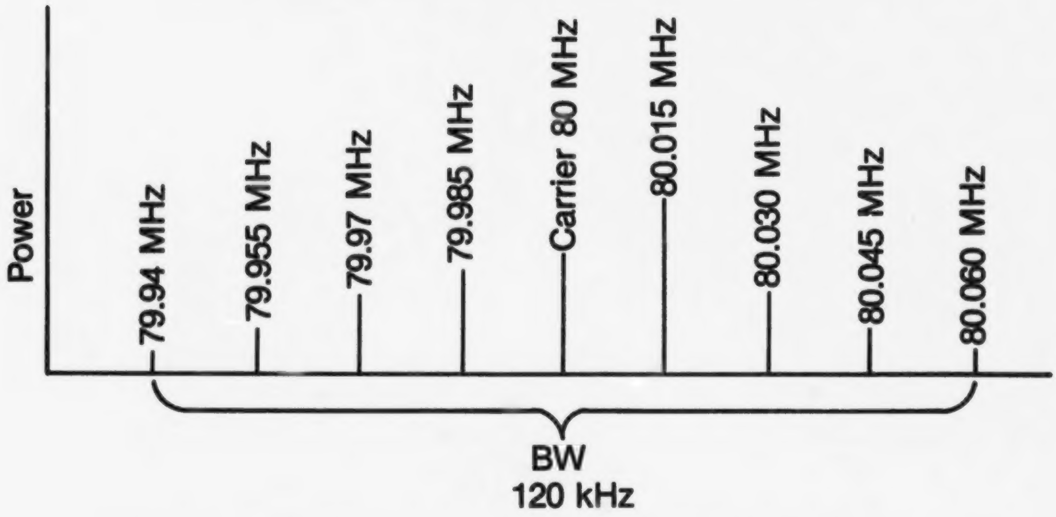
Phase

Diode Modulator


R1
R2
D1
R3
L1
C1
Output

Modulation Index

Modulation Index	Significant Sidebands
.01	2
.4	2
.5	4
1.0	6
2.0	8
3.0	12
4.0	14
5.0	16
6.0	18
7.0	22
8.0	24
9.0	26
10.0	28
11.0	32
12.0	32
13.0	36
14.0	38
15.0	38


Power
79.94 MHz
79.955 MHz
79.97 MHz
79.985 MHz
Carrier 80 MHz
80.015 MHz
80.030 MHz
80.045 MHz
80.060 MHz
BW
120 kHz

Spectrum Distribution for a Modulation Index of "2"

MODULATION/DEMODULATION TECHNIQUES
UNIT VI

ASSIGNMENT SHEET #1 — CALCULATE PERCENT OF MODULATION

NAME ____________________ SCORE ____________________

Directions: Use the following formula to calculate percent of modulation for the waveforms illustrated.

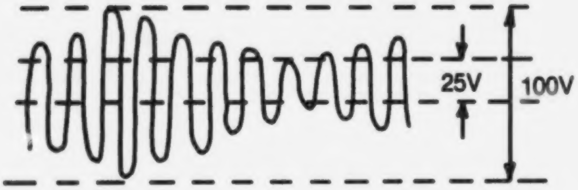
$$\text{Percent modulation} = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} \times 100$$

Emax = Maximum peak-to-peak amplitude of the modulated carrier wave

Emin = Minimum peak-to-peak amplitude of the modulated carrier wave

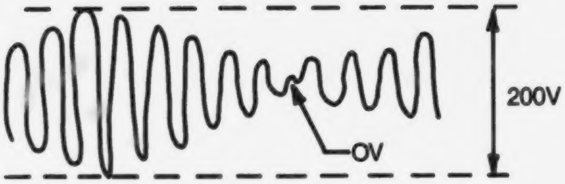
1. Given the amplitude modulated waveform, what is the percent of modulation?

____



2. Given the amplitude modulated waveform, what is the percent of modulation?

____



MODULATION/DEMODULATION TECHNIQUES
UNIT VI

ASSIGNMENT SHEET #2 — CALCULATE MODULATION INDEX

NAME ____________________ SCORE ____________________

Directions: Using the formula given, calculate the deviation ratios for the situations stated in the problems.

$$\text{Modulation Index} = \frac{\text{Deviation in frequency}}{\text{Modulating frequency}}$$

1. What is the modulation index if a 45-MHz carrier is deviated ± 5 kHz by a 5000 Hz modulating signal? Show your calculations. __________

2. What is the modulation index if a 45-MHz carrier is deviated ± 25 kHz by a 1000 Hz modulating signal? Show your calculations. __________

MODULATION/DEMODULATION TECHNIQUES
UNIT VI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 60 percent
2. 100 percent

Assignment Sheet #2

1. 2
2. 50

MODULATION/DEMODULATION TECHNIQUES
UNIT VI

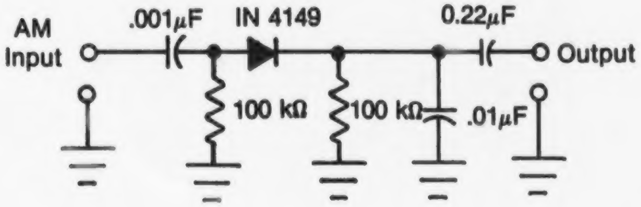
JOB SHEET #1 — CONSTRUCT AND ANALYZE A DIODE DETECTOR

A. Equipment and materials needed

1. AM generator
2. 0.001 uF capacitor
3. Two 100 K resistors
4. 1N4149 diode or equivalent
5. 0.22 uF capacitor
6. 0.01 uF capacitor
7. Oscilloscope

B. Procedure

1. Construct a diode detector according to the following schematic.



2. Apply an amplitude modulated waveform to the input of the circuit.
3. Connect the oscilloscope to view the waveform at the input to the circuit.

JOB SHEET #1

4. Sketch the approximate waveform viewed on the oscilloscope.

5. Connect the oscilloscope to view the waveform at the output terminal of the circuit.

6. Sketch the approximate waveform viewed on the oscilloscope.

7. Turn off all power to your equipment.

8. Disassemble the circuit.

9. Return equipment and materials to their proper storage location.

MODULATION/DEMODULATION TECHNIQUES
UNIT VI

JOB SHEET #1 PRACTICAL TEST — CONSTRUCT AND ANALYZE A DIODE DETECTOR

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Properly constructed the circuit according to the schematic diagram.	______	______
3. Properly connected the AM generator or service monitor to the circuit.	______	______
4. Adjusted the AM generator or service monitor for proper operation.	______	______
5. Set the oscilloscope for proper operation.	______	______
6. Properly connected the oscilloscope to the circuit.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Circuit construction	4 Correct	3	2	1 Incorrect
AM input waveform	4 Proper waveform Properly synchronized Focused	3	2	1 Incorrect waveform Out of sync Not focused
Detected output waveform	4 Proper waveform Properly synchronized Focused	3	2	1 Incorrect waveform Out of sync Not focused

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

MODULATION/DEMODULATION TECHNIQUES
UNIT VI

TEST

NAME ____________________ SCORE ____________________

1. Match the terms on the right with their correct definitions.

_____a. The process by which the alteration or modification of the characteristics of one waveform or signal is accomplished in accordance with the characteristic of another waveform called a modulation signal

_____b. The process of removing the modulation signal from the associated carrier waveform

_____c. Method of mixing the audio and RF in the plate/collector circuit of the last stage RF amplifier.

_____d. A continuous wave radio frequency to which intelligence may be added by the process of modulation

_____e. Electronic signal that conveys information such as voice, music, or data

_____f. Process of combining two signals of different frequencies to obtain another frequency different from the original

_____g. Method of mixing the audio and RF at a point in the transmitter prior to the plate/collector of the last stage RF amplifier

_____h. Frequencies above and below the carrier frequency as a result of modulation

_____i. Modulation in which the amplitude of the carrier is the characteristic that is varied

_____j. Modulation in which the frequency of the carrier is the characteristic that is varied

1. Amplitude modulation
2. Carrier
3. Demodulation
4. Frequency modulation
5. Heterodyne
6. High level modulation
7. Intelligence signal
8. Low level modulation
9. Modulation
10. Sideband frequencies

TEST

2. Complete the following statements concerning basic principles of the modulation process by inserting the word(s) which best completes each statement.

   a. Modulation is a process through which the characteristics of a high-frequency carrier waveform is varied in accordance with the waveform of a superimposed intelligence signal such as ____________ or ____________.

   b. Three characteristics of a sine wave carrier which may be varied are ____________, ____________, and ____________.

3. Select true statements concerning basic requirements of the demodulation process by placing an "X" in the blanks preceding the true statements.

   _____a. Demodulator input circuit must be sensitive to the modulation characteristics.

   _____b. Linearity must be present.

   _____c. An RF carrier signal must be present at the input of the demodulator to heterodyne with the sideband signals to reproduce the original intelligence signal.

   _____d. Filtering is required at the output of the demodulator to select the desired intelligence signal and reject the unwanted RF frequencies.

4. Complete the following statements concerning the characteristics of amplitude modulation by inserting the word(s) which best complete(s) each statement.

   a. Amplitude modulation exists when the ____________ of a carrier waveform is varied with a modulating frequency and voltage while the ____________ of the carrier is held constant.

   b. A modulated carrier contains the carrier frequency plus ____________ new sideband frequencies.

   c. The ____________ of the modulated carrier is the algebraic sum of the instantaneous amplitudes of the unmodulated carrier and the upper frequency and the lower frequency signals.

   d. The ____________ of the amplitude modulated signal refers to the space the transmitted signal will occupy in the frequency spectrum.

   e. The ____________ power radiated in an amplitude modulated carrier wave is equal to the sum of the power contained in the separate components of the modulated wave.

TEST

f. When a carrier is modulated at 100%, total sideband power is ____________ the carrier power.

g. When a carrier is modulated at 100%, the carrier contains ____________ of the total power.

h. When a carrier is modulated at 100%, total sideband power is ____________ of the total transmitted power.

i. When a carrier is modulated at 100%, sideband power is distributed ____________ in two sidebands.

j. When a carrier is modulated at 100%, each sideband contains ____________ of the total power.

k. ____________ produces severe distortion which produces new modulating frequencies causing a considerable increase in bandwidth of the transmitted signal.

5. Complete the following statements concerning the characteristics of single-sideband modulation by inserting the word(s) which best complete each statement.

a. Single-sideband operation involves the transmission of only ____________ sideband.

b. With single sideband transmission systems

1) A ____________ is modulated with an intelligence signal.

2) The ____________ is suppressed.

3) One of the two ____________ is eliminated.

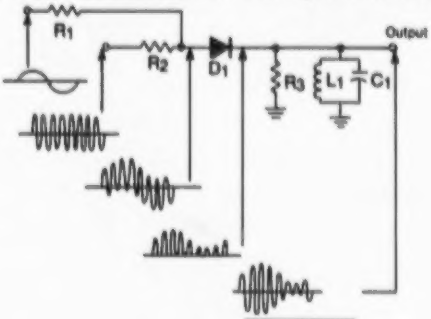
c. An ____________ signal, a ____________ signal, a balanced ____________ circuit, and a ____________ filter is needed to generate a single-sideband signal.

TEST

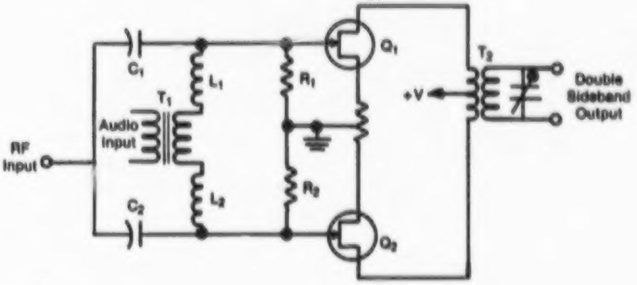
6. Match types of AM modulators on the right with their schematic diagrams.

1. The diode modulator
2. Integrated circuit balanced modulator
3. A series modulator
4. Progressive series modulator
5. Twin-FET balanced modulator

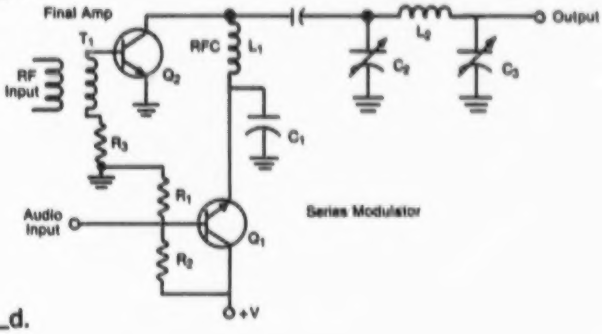
_____a.


R1
R2
D1
Output
R3
L1
C1

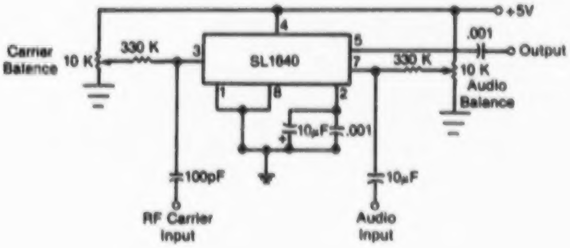
_____b.


C1
T1
Audio Input
L1
R1
Q1
T2
+V
Double Sideband Output
RF Input
C2
L2
R2
Q2

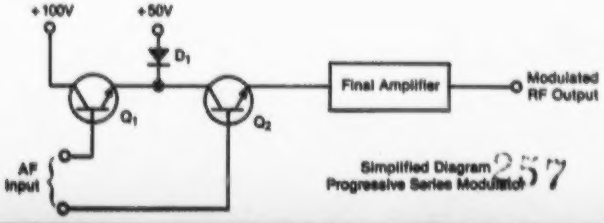
_____c.


Final Amp
T1
RF Input
Q2
RFC
L1
L2
C2
C3
Output
C1
R3
R1
Audio Input
Q1
R2
+V
Series Modulator

_____d.


+5V
4
5
.001
Output
Carrier Balance
10 K
330 K
3
SL1640
7
330 K
10 K
Audio Balance
1
8
2
10µF
.001
100pF
RF Carrier Input
10µF
Audio Input

_____e.


+100V
+50V
D1
Q1
Q2
Final Amplifier
Modulated RF Output
AF Input

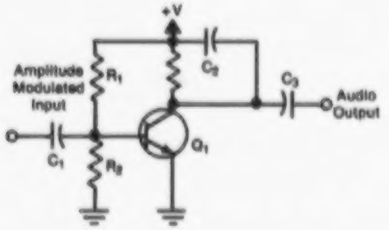
Simplified Diagram
Progressive Series Modulator

TEST

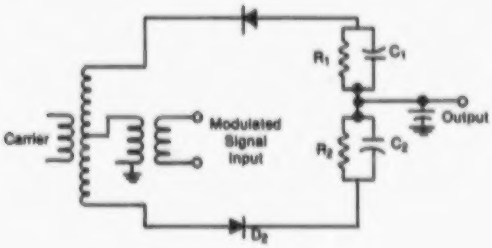
7. Match the types of AM demodulators on the right with their schematic diagrams.

1. The diode detector
2. Transistor detector
3. Synchronous detector

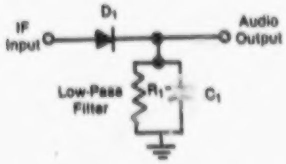
_____a.


+V
C2
C3
Amplitude Modulated Input
R1
Audio Output
C1
R2
Q1

_____b.


R1
C1
Carrier
Modulated Signal Input
Output
R2
C2
D2

_____c.


D1
IF Input
Audio Output
Low-Pass Filter
R1
C1

8. Select true statements concerning characteristics of frequency modulation by placing an "X" in the blanks preceding the true statements.

_____a. Frequency modulation is angle modulation of a sinusoidal carrier.

_____b. The instantaneous frequency of the modulated wave differs from the carrier frequency by an amount proportional to the instantaneous amplitude of the modulating frequency.

_____c. The modulating signal is the carrier signal.

_____d. The unmodulated carrier frequency in FM is called the center frequency.

TEST

_____e. The center frequency is present only when there is no modulation applied.

_____f. When a modulating frequency is present with a negative amplitude the frequency of the modulated waveform is lower than the center frequency.

_____g. When a modulating frequency is present with a negative amplitude the frequency of the modulated waveform is higher than the center frequency.

9. Complete the following statements concerning frequency deviation in FM systems by inserting the word(s) which best complete(s) each statement.

   a. The difference between the instantaneous frequency of the modulated wave and the carrier frequency is called the frequency ____________.

   b. The oscillator oscillates at the ____________ frequency when no modulating signal is applied.

   c. An ____________ signal from the modulator will cause the oscillator to change frequency above and below the center frequency.

   d. Maximum ____________ will occur at the voltage peak of the modulating signal.

   e. The amount of deviation of the oscillator is determined by the ____________ of the modulating signal.

   f. Maximum deviation occurs at the peak ____________ of the modulating signal.

   g. The ____________ of the modulating signal determines the rate of deviation of the oscillator above and below the center frequency.

10. Write the formula for determining modulation index.

TEST

11. Distinguish between types of FM modulators by placing an "R" for reactance modulator next to the correct description.

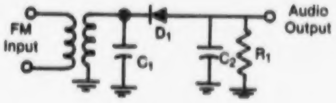
    _____a. Incorporates direct modulation process where the master oscillator frequency is varied in accordance with the modulating signal; it cannot be used with a crystal controlled oscillator and therefore requires additional frequency control circuitry.

    _____b. Offers simplicity, reliability, and stability; crystal oscillator provides stability.

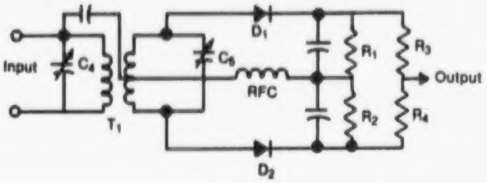
12. Match types of FM demodulators on the right with their schematic diagrams.

1. Slope detector
2. Varactor demodulator
3. Foster-Seeley discriminator
4. Reactance demodulator

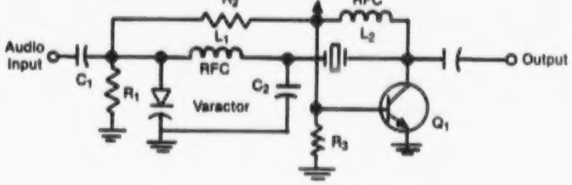
_____a.


FM Input
D1
Audio Output
C1
C2
R1

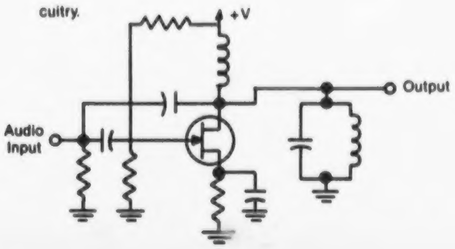
_____b.


Input
C4
T1
C5
D1
RFC
R1
R2
R3
R4
Output
D2

_____c.


+V
R2
RFC
L2
L1
Audio Input
RFC
C1
R1
Varactor
C2
Output
Q1
R3

_____d.


cuitry.
+V
Output
Audio Input

TEST

13. Complete the following statements concerning characteristics of phase modulation by inserting the word(s) which best complete(s) each statement.

    a. A phase-modulated waveform is produced by shifting the ____________ of the carrier with respect to the modulating voltage while maintaining the amplitude of the carrier constant.

    b. The rate at which a phase-modulated wave shifts from one phase value to another is proportional to the ____________ of the modulating voltage.

    c. The number of degrees through which the phase of the carrier is shifted is proportional to the ____________ of the modulating voltage.

    d. The ____________ of the modulating signal determines the number of significant sidebands.

    e. Sidebands are spaced on either side of the carrier by an amount equal to the modulating signal ____________.

    f. The sidebands contain the ____________ signal .

    g. Increasing the amplitude or frequency of the modulating signal increases the ____________ of the transmitted signal.

    h. ____________ modulation techniques are employed in phase modulation providing for good frequency stability.

    i. Output is fed to class C amplifiers which remove ____________ variations.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

14. Calculate percent of modulation. (Assignment Sheet #1)

15. Calculate modulation index. (Assignment Sheet #2)

16. Demonstrate the ability to construct and analyze a diode detector. (Job Sheet #1)

MODULATION/DEMODULATION TECHNIQUES
UNIT VI

ANSWERS TO TEST

1. a. 9
   b. 3
   c. 6
   d. 2
   e. 7
   f. 5
   g. 8
   h. 10
   i. 1
   j. 4

2. a. Music, voice
   b. Amplitude, frequency, phase

3. a, c, d

4. a. Amplitude, frequency
   b. Two
   c. Amplitude
   d. Bandwidth
   e. Total
   f. One-half
   g. Two-thirds
   h. One-third
   i. Equally
   j. One-sixth
   k. Overmodulation

5. a. One
   b. 1) Carrier
      2) Carrier
      3) Sidebands
   c. Intelligence, carrier, modulator, low-pass

6. a. 1
   b. 5
   c. 3
   d. 2
   e. 4

7. a. 2
   b. 3
   c. 1

8. a, b, d, e

9. a. Deviation
   b. Center
   c. Intelligence
   d. Deviation
   e. Amplitude
   f. Amplitude
   g. Frequency

ANSWERS TO TEST

10. Modulation index (MI) = $\dfrac{fd}{fm}$ (frequency deviation)
(frequency of the modulating signal)

11. a

12.
    a. 1
    b. 3
    c. 2
    d. 4

13.
    a. Phase
    b. Frequency
    c. Amplitude
    d. Amplitude
    e. Frequency
    f. Intelligence
    g. Bandwidth
    h. Indirect
    i. Amplitude

14.-15. Evaluated to the satisfaction of the instructor

16. Performance skills evaluated according to industry standards and to the satisfaction of the instructor

RECEIVERS
UNIT VII

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify stages in a radio receiver and explain the functional characteristics of each stage. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to receivers with their correct definitions.
2. Match the stages in an AM superheterodyne receiver block diagram with their correct names.
3. Complete statements concerning the functional characteristics of stages in an AM receiver.
4. Match the stages in a single-sideband receiver block diagram with their correct names.
5. Complete statements concerning the functional characteristics of stages in a single-sideband receiver.
6. Match stages in an FM receiver block diagram with their correct names.
7. Complete statements concerning the functional characteristics of stages in an FM receiver.
8. Select true statements concerning the characteristics of double conversion receivers.

OBJECTIVE SHEET

9. Complete statements concerning the characteristics of AGC and AFC circuits.
10. Select true statements concerning specifications for receivers.
11. Distinguish between WWV and WWVH frequency standards.
12. Demonstrate the ability to:
    a. Identify the stages in an AM receiver and on its associated schematic. (Job Sheet #1)
    b. Identify the stages in an FM receiver and on its associated schematic. (Job Sheet #2)
    c. Tune in and analyze time tones. (Job Sheet #3)
    d. Tune in and analyze frequency tones. (Job Sheet #4)

RECEIVERS
UNIT VII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate alignment procedures of a radio receiver.
2. Tour a radio broadcast station.
3. Visit a radio sales and service center.
4. Build a receiver using a purchased kit.
5. Perform an alignment of the kit receiver.
6. Demonstrate AGC operation.
7. Demonstrate AFC operation.
8. Demonstrate the operation of a limiter circuit.
9. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN WRITING THIS UNIT

A. *Electronic Communications*. Benton Harbor, MI: Heath Company, 1981.

B. Hardy, James K. *Electronic Communications Technology*. Englewood Cliffs, NJ: Prentice-Hall, 1986.

C. Kennedy, George. *Electronic Communication Systems*. Third Edition. New York: McGraw-Hill Book Company, 1985.

D. Schrader, Robert L. *Electronic Communication*. Fifth Edition. New York: McGraw-Hill Book Company, 1985.

E. Miller, Gary M. *Modern Electronic Communication*. Third Edition. Englewood Cliffs, NJ: Prentice-Hall, 1983.

F. Gerrish, Howard H. and Dugger, William E. *Electricity and Electronics*. South Holland, IL: Goodheart-Willcox Company, Inc., 1980.

RECEIVERS
UNIT VII

INFORMATION SHEET

I. **Terms and definitions**

A. AFC (automatic frequency control) — An electronic circuit that assures a constant IF center frequency in an FM receiver by keeping the local oscillator frequency separated from the RF amplifier signal by a fixed amount

B. AM receiver — An apparatus of electronic circuits designed to receive and process amplitude modulated signals

C. AVC/AGC (automatic volume/gain control) — An electronic circuit that automatically increases or decreases the gain of a receiver in an inverse relationship with the strength of the received signal

D. Co-channel interference — Interfering signal of the same frequency as the desired signal

E. Converter — A stage in a receiver that is a combination local oscillator and mixer

F. Detector — The stage in a receiver that separates the intelligence signal from the IF frequency

G. Discriminator — The electronic circuit in an FM receiver that separates the intelligence signal from the IF

H. Double conversion — Two stage process of producing first one intermediate frequency followed by the production of a second intermediate frequency

I. FM receiver — An apparatus of electronic circuits designed to receive and process frequency modulated signals

J. IF (intermediate frequency) — The frequency that results from mixing an RF signal from the RF amplifier with the local oscillator RF frequency

K. Image frequency — An unwanted signal that arises from a source other than that to which the receiver is tuned, usually during heterodyning action in the mixer whose frequency falls within the bandpass of the IF amplifier

L. Image rejection ratio — The ratio of the desired signal amplitude to the image signal amplitude

M. Limiter — Designed to insure constant amplitude

N. Local oscillator — The stage in a receiver which produces an unmodulated variable RF frequency

INFORMATION SHEET

O. Mixer — The stage in a receiver which heterodynes the RF signal from the receiving antenna and the RF frequency generated by the local oscillator

P. Noise - Undesirable interference in an electronic signal

Q. Receiver — An apparatus of electronic circuits that receives a signal and processes the signal into a recognizable form such as voice or data

R. Selectivity — The ability of a receiver to select one signal and reject all others

S. Sensitivity — The ability of a receiver to amplify a small signal

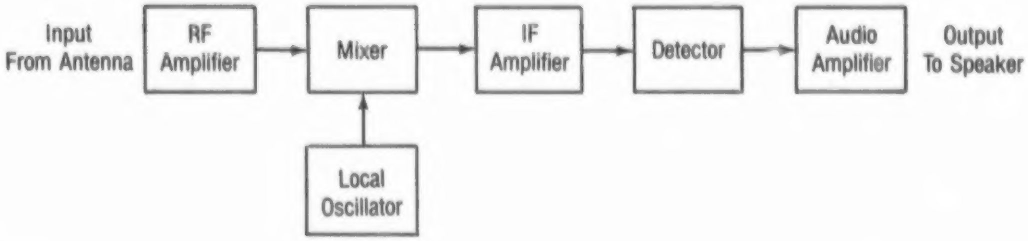
T. Single conversion — The process of producing a single intermediate frequency (IF) in a superheterodyne receiver

U. Squelch circuit — Circuit for preventing a radio receiver from producing audio frequency output in the absence of the predetermined signal

II. **Stages in an AM superheterodyne receiver block diagram** (Transparency 1)

A. A superheterodyne receiver has six major stages

1. RF amplifier
2. Mixer
3. Local oscillator
4. IF amplifier
5. Detector
6. Audio amplifier


Input From Antenna
RF Amplifier
Mixer
IF Amplifier
Detector
Audio Amplifier
Output To Speaker
Local Oscillator

INFORMATION SHEET

B. An antenna is used as the signal source and usually a speaker as the output transducer

III. **Functional characteristics of stages in an AM receiver** (Transparency 2)

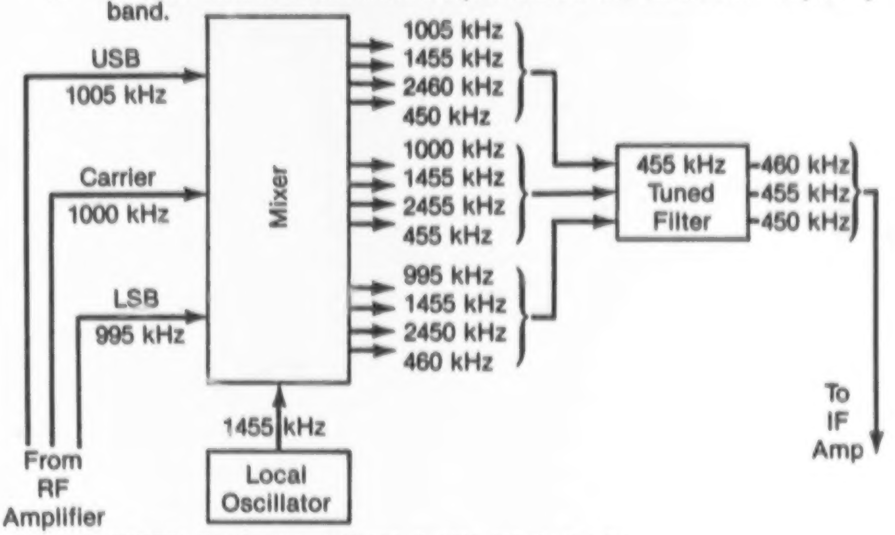
A. The characteristics of the RF amplifier stage and associated input circuitry allow it to perform numerous functions.

1. Amplifies the incoming RF signal
2. Isolates the oscillator from the antenna preventing radiation from the receiver
3. Isolates the mixer from the antenna improving the image frequency rejection of the receiver
4. Variable tuning input circuitry selects the desired carrier frequency
5. Operates over a wide band of frequencies

B. The local oscillator produces a sine wave of a frequency which differs from the desired station frequency by an amount equal to the intermediate frequency.

C. The mixer heterodynes the carrier and sideband frequencies producing ten significant frequencies at its output.

1. Sum and difference frequencies are produced for each pair of frequencies at the input to the mixer.
2. A tuned circuit at the mixer output selects the desired IF frequency band.


USB
1005 kHz
Carrier
1000 kHz
LSB
995 kHz
From
RF
Amplifier
Mixer
1455 kHz
Local
Oscillator
1005 kHz
1455 kHz
2460 kHz
450 kHz
1000 kHz
1455 kHz
2455 kHz
455 kHz
995 kHz
1455 kHz
2450 kHz
460 kHz
455 kHz
Tuned
Filter
460 kHz
455 kHz
450 kHz
To
IF
Amp

(NOTE: Carrier is modulated with single tone.)

INFORMATION SHEET

D. The IF amplifier amplifies the mixer output signal and applies it to the detector stage.

   1. Because they operate at a fixed frequency (commonly 455 kHz in broadcast receivers), the IF amplifiers have optimum gain and bandwidth characteristics

   2. IF amplifiers serve a major role in determining receiver selectivity

   3. Operate as class-A voltage amplifiers

E. The detector recovers the intelligence from the modulated wave

F. The audio amplifier increases the power of the intelligence signal to a level sufficient to drive the output device (earphones, speaker, etc)

IV. **Stages in a single-sideband (SSB) receiver block diagram**

A. RF amplifier

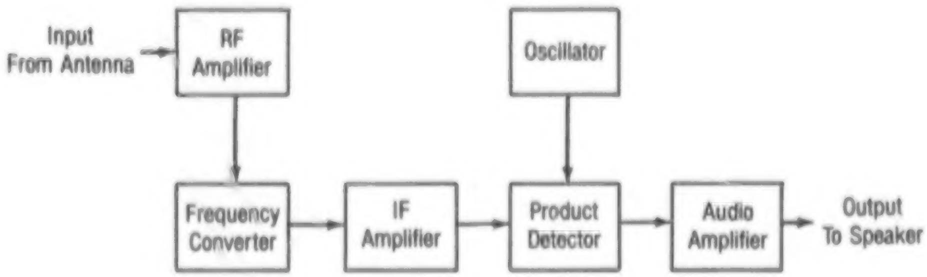
B. Frequency converter

C. IF amplifier

D. Oscillator

E. Product detector

F. Audio amplifier


Input
From Antenna
RF
Amplifier
Oscillator
Frequency
Converter
IF
Amplifier
Product
Detector
Audio
Amplifier
Output
To Speaker

INFORMATION SHEET

V. **Functional characteristics of stages in a single-sideband receiver**

A. The RF amplifier in a SSB receiver operates similar to that of the standard AM receiver except that its bandwidth is narrower.

B. The frequency converter and IF amplifier are similar in operation to that in an AM receiver.

1. Bandwidth of the stages is narrow compared to AM.

2. Bandwidth would be one-half that of AM to pass the same intelligence signal.

C. The function of the demodulator, typically a product detector, is to remove the intelligence signal from the carrier.

1. Sidebands and carrier are needed for demodulation

2. Carrier frequency supplied by reference frequency oscillator

3. Sideband frequencies supplied by the IF amplifiers

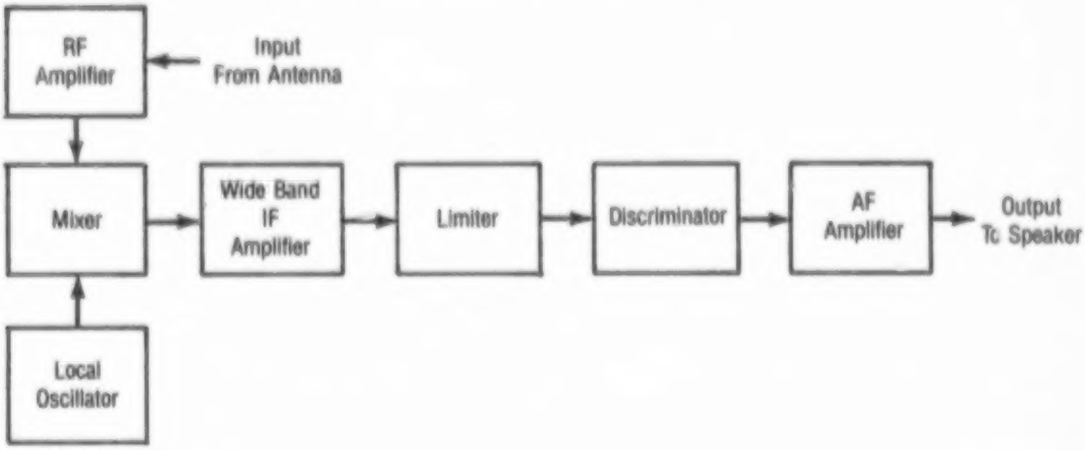
D. The reference frequency oscillator generates the same frequency as the carrier oscillator in the transmitter.

1. Must have high frequency and amplitude stability

2. Output is heterodyned with IF in demodulator

E. The audio amplifier raises the level of the intelligence signal to that required to drive the output transducer.

VI. **Stages in an FM receiver block diagram** (Transparency 3)


RF Amplifier
Input From Antenna
Mixer
Wide Band IF Amplifier
Limiter
Discriminator
AF Amplifier
Output To Speaker
Local Oscillator

INFORMATION SHEET

VII. Functional characteristics of stages in an FM receiver

A. The function of the RF amplifier is very similar to that in an AM receiver with the primary difference being the frequency of operation and bandwidth.

B. The function of the mixer stage is similar to that of the AM receiver except for the frequencies processed.

C. The IF amplifier stage operates similar to that in an AM receiver except for the IF frequency, typically 10.7 MHz in broadcast receivers.

D. The function of the limiter stage in an FM receiver is to remove any amplitude variations that may be present in the IF signal.

(NOTE: The amplitude variations are interference signals that could be demodulated and reproduced by the output transducer as noise.)

E. The demodulator produces an audio signal whose frequency is determined by the rate of frequency deviation, and whose amplitude is determined by the amount of deviation in the incoming frequency.

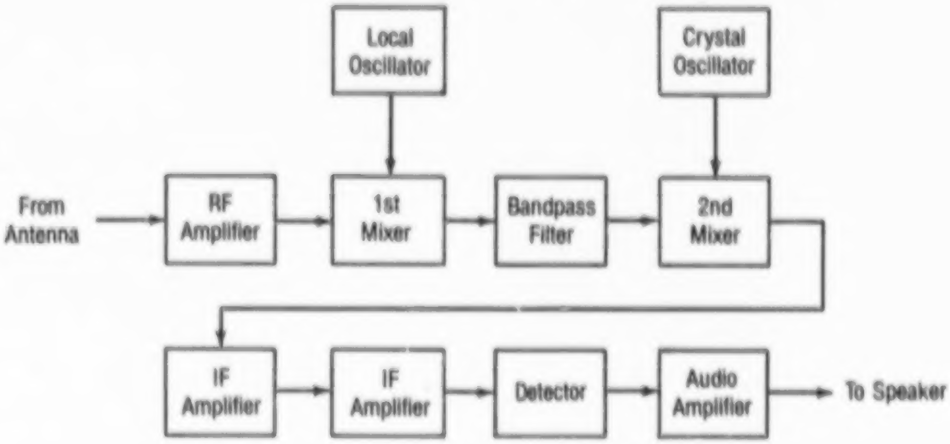
F. The audio amplifier increases the demodulated signal to a power level sufficient to drive the output transducer.

VIII. Characteristics of double conversion receivers

A. A double-conversion receiver is designed to take advantage of both low and high IF frequencies.

B. High IF frequency is used first for good image frequency rejection.

C. Low second IF frequency provides for improved selectivity and improved gain characteristics.

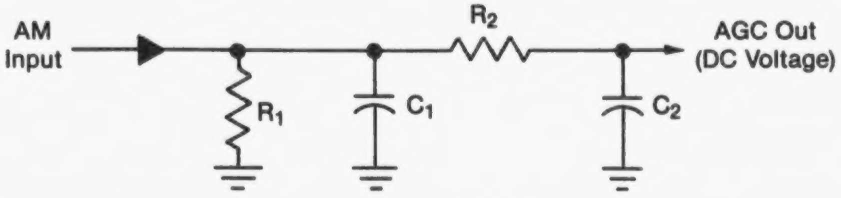

Local Oscillator
Crystal Oscillator
From Antenna
RF Amplifier
1st Mixer
Bandpass Filter
2nd Mixer
IF Amplifier
IF Amplifier
Detector
Audio Amplifier
To Speaker

INFORMATION SHEET

IX. Characteristics of automatic gain/frequency control (AGC/AVC) circuits

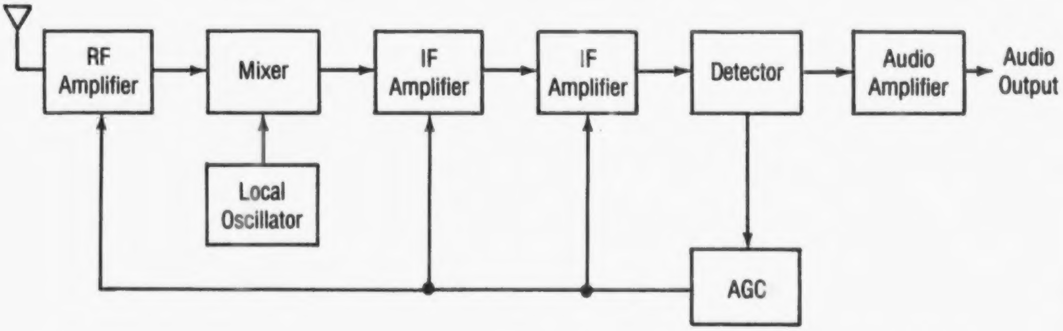
A. AGC is a circuit that automatically varies the gain of a receiver to maintain the volume at a constant level regardless of the strength of the input signal.

B. An AGC circuit derives a DC feedback control voltage from the detected intelligence signal.

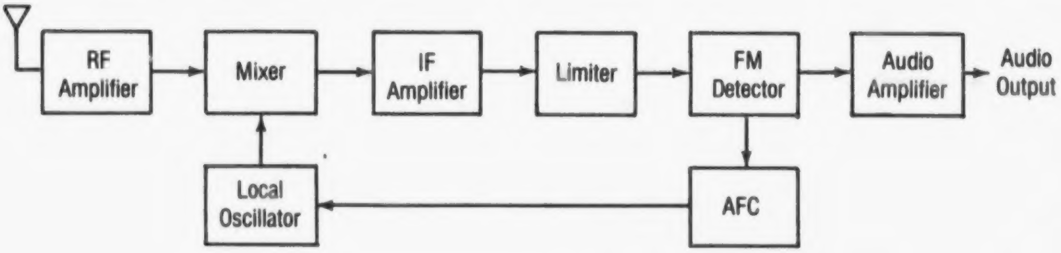

AM Input
R₂
AGC Out (DC Voltage)
R₁
C₁
C₂

(NOTE: The above is one of the simplest AGC circuits. Other types of circuits may be used to accomplish the same purpose.)

C. The AGC voltage in AM receivers is used to automatically vary the bias and therefore the gain of the RF and IF amplifiers.


RF Amplifier
Mixer
IF Amplifier
IF Amplifier
Detector
Audio Amplifier
Audio Output
Local Oscillator
AGC

D. Automatic frequency control (AFC) circuits in FM receivers use a feedback system to develop a DC control voltage to be applied to the varactor diode in the oscillator circuit.


RF Amplifier
Mixer
IF Amplifier
Limiter
FM Detector
Audio Amplifier
Audio Output
Local Oscillator
AFC

INFORMATION SHEET

X. Specifications for receivers

A. Sensitivity is the measure of the amplitude of the weakest signal that can be received without it being obliterated by noise and is specified as the signal-to-noise ratio of the receiver.

B. Selectivity is the measure of the receiver's ability to select the desired frequency and reject all other frequencies.

C. Image rejection is the measure of the receiver's ability to reject a strong signal at the exact image frequency.

D. Dynamic range is a measure of the ability of a receiver to receive both very weak signals and very strong signals without introducing distortion in either.

XI. Frequency standards and their characteristics

(NOTE: WWV and WWVH are station call letters for National Bureau of Standards [NBS] broadcast radio.)

A. WWV (Transparency 4)

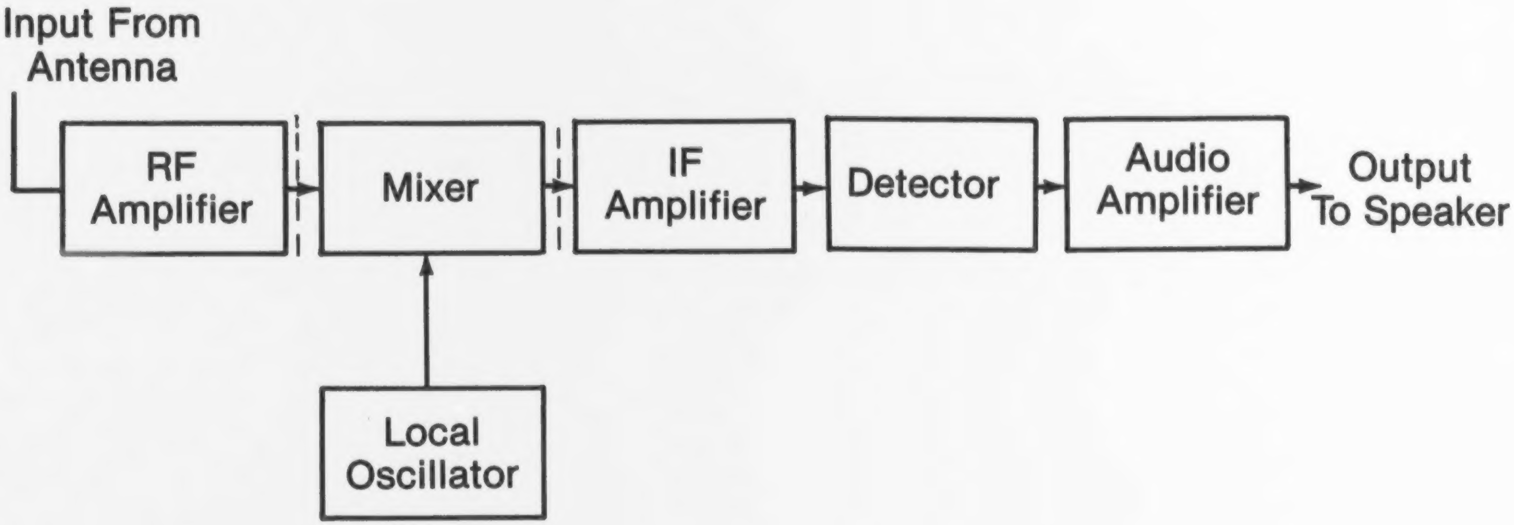
1. Transmitted on frequencies of 2.5, 5, 10, 15, and 20 MHz
2. Broadcasts a male voice
3. The announcement occurs 7.5 seconds before the minute
4. The beginning of each hour is identified by an 800 m sec 1.5 KHz tone
5. The beginning of each minute is identified by an 800 m sec 1 KHz tone
6. Each second, except the 29th and 59th, a 5 m sec pulse of 1 KHz is transmitted
7. Each hour a 440 Hz tone is broadcast as a marker for chart records and other automated electronic equipment
8. Each alternate minute a 500 or 600 Hz tone is broadcast

INFORMATION SHEET

B. WWVH (Transparency 5)

1. Transmitted on frequencies of 2.5, 5, 10, and 15 MHz
2. Broadcasts a female voice
3. The announcement occurs 15 seconds before the minute
4. The beginning of each hour is identified by an 800 m sec 1.5 KHz tone
5. The beginning of each minute is identified by an 800 m sec 1.2 KHz tone
6. Each second, except the 29th and 59th, a 5 m sec pulse of 1 KHz is transmitted
7. Each hour a 440 Hz tone is broadcast as a marker for chart recorders and other automated electronic equipment
8. Each alternate minute a 500 or 600 Hz tone is broadcast

AM Superheterodyne Receiver Block Diagram



Input From Antenna

RF Amplifier

Mixer

IF Amplifier

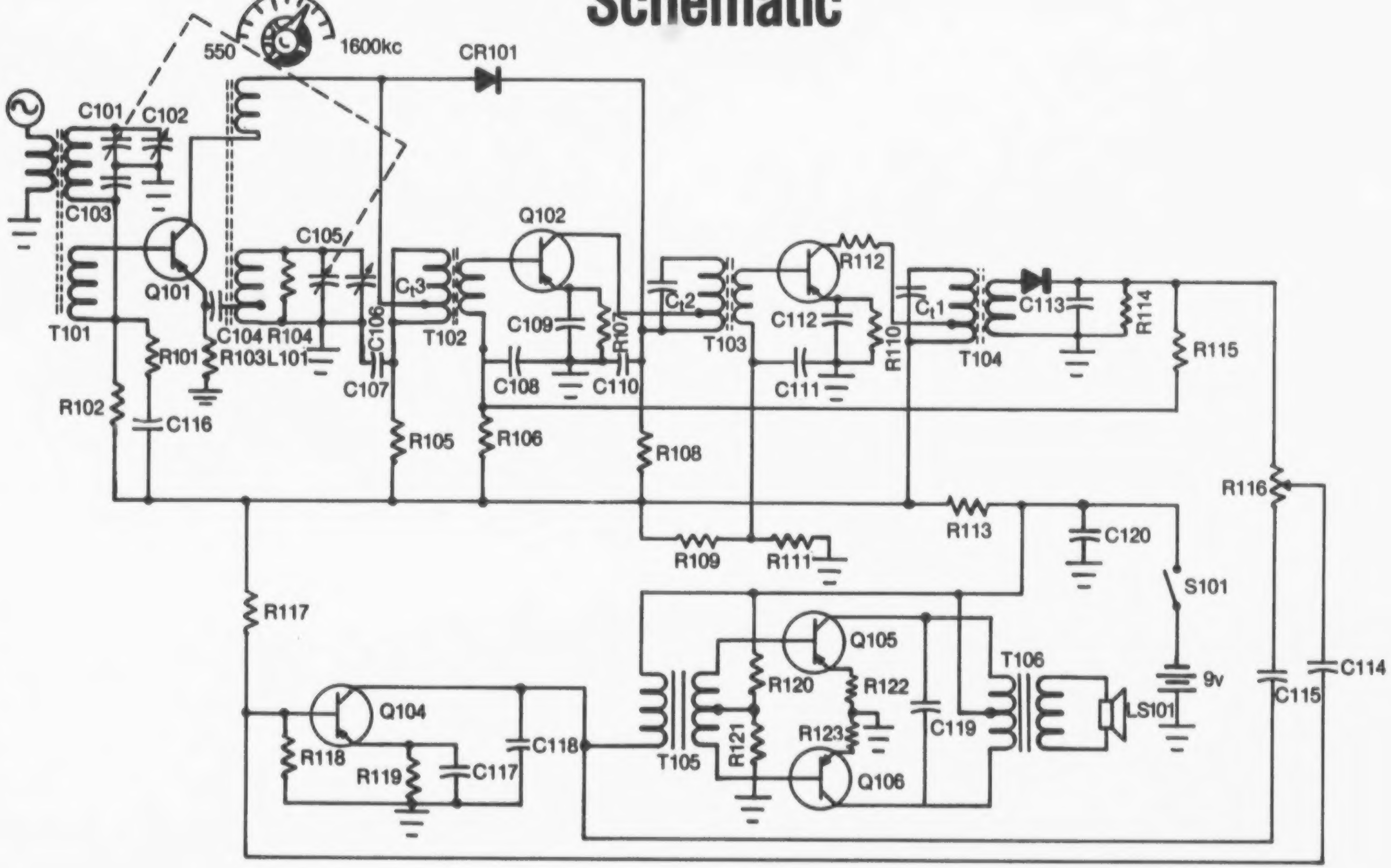
Detector

Audio Amplifier

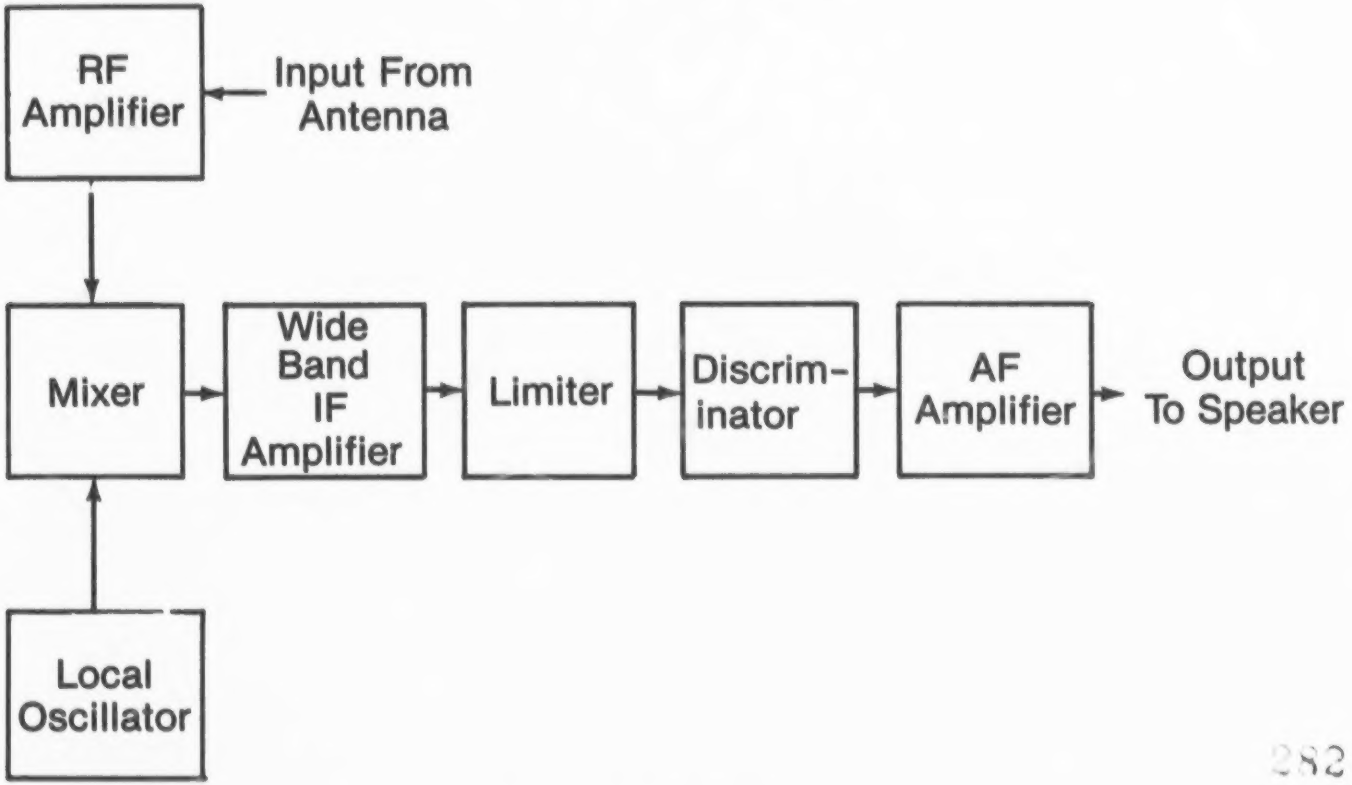
Output To Speaker

Local Oscillator

Typical AM Broadcast Receiver Schematic


550
1600kc
CR101
C101
C102
C103
Q101
T101
C104
R104
R101
R103
L101
R102
C116
C105
C106
C107
Ct3
T102
Q102
C109
R107
C108
C110
R105
R106
Ct2
T103
R108
Q103
R112
C112
R110
C111
R109
R111
Ct1
T104
C113
R114
R115
R113
C120
S101
R116
R117
Q104
R118
R119
C117
C118
T105
R120
R121
Q105
R122
R123
Q106
C119
T106
LS101
9v
C115
C114

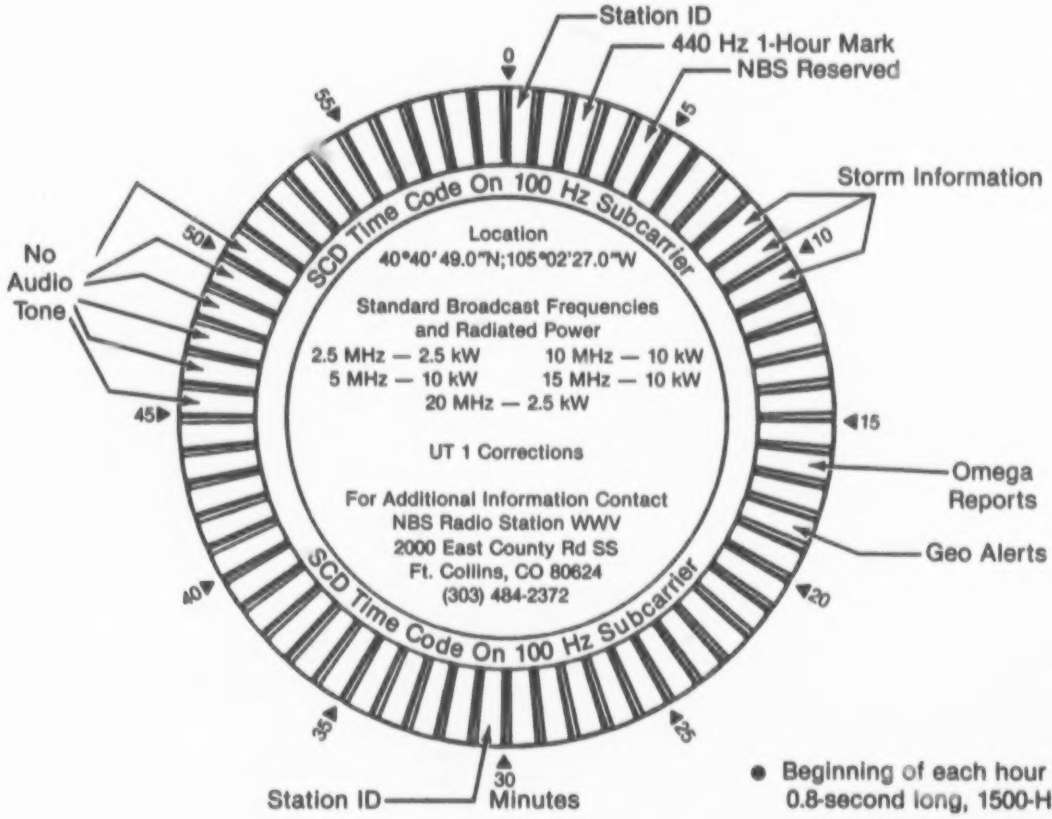
FM Broadcast Receiver
Block Diagram

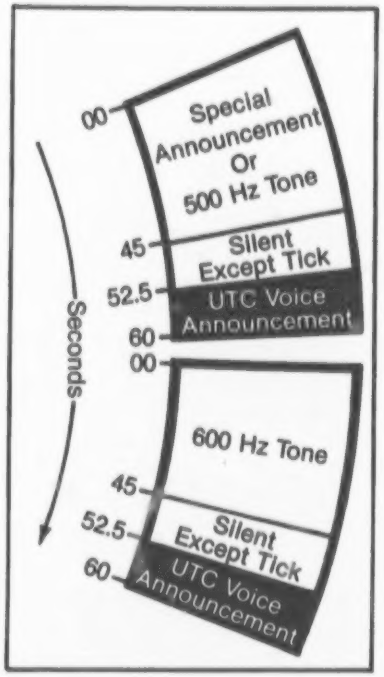

RF Amplifier
Input From Antenna
Mixer
Wide Band IF Amplifier
Limiter
Discrim-inator
AF Amplifier
Output To Speaker
Local Oscillator

282

281

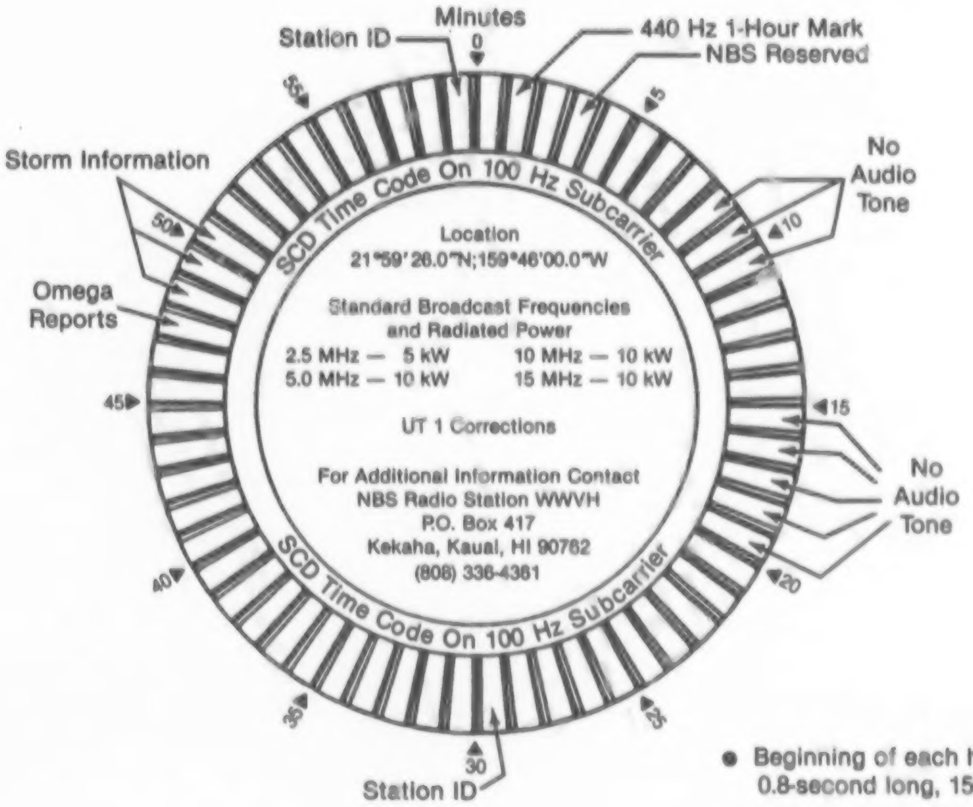
NBS WWV Broadcast Format

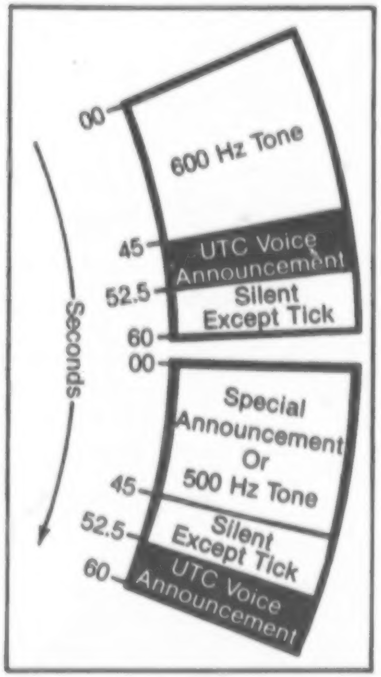

Station ID
440 Hz 1-Hour Mark
NBS Reserved
0
5
10
15
20
25
30
35
40
45
50
55
Storm Information
Omega Reports
Geo Alerts
Station ID
30 Minutes
No Audio Tone
SCD Time Code On 100 Hz Subcarrier
Location
40°40′49.0″N;105°02′27.0″W
Standard Broadcast Frequencies and Radiated Power
2.5 MHz — 2.5 kW
5 MHz — 10 kW
10 MHz — 10 kW
15 MHz — 10 kW
20 MHz — 2.5 kW
UT 1 Corrections
For Additional Information Contact
NBS Radio Station WWV
2000 East County Rd SS
Ft. Collins, CO 80624
(303) 484-2372
SCD Time Code On 100 Hz Subcarrier


00
Special Announcement Or 500 Hz Tone
45
Silent Except Tick
52.5
UTC Voice Announcement
60
00
600 Hz Tone
45
52.5
Silent Except Tick
60
UTC Voice Announcement
Seconds

- Beginning of each hour is identified by 0.8-second long, 1500-Hz tone.
- Beginning of each minute is identified by 0.8-second long, 1000-Hz tone.
- The 29th & 59th second pulse of each minute is omitted.

NBS WWVH Broadcast Format


Minutes
0
Station ID
440 Hz 1-Hour Mark
NBS Reserved
5
55
No Audio Tone
10
Storm Information
50
Omega Reports
45
15
No Audio Tone
40
20
35
25
30
Station ID
SCD Time Code On 100 Hz Subcarrier
Location
21°59'26.0"N;159°46'00.0"W
Standard Broadcast Frequencies and Radiated Power
2.5 MHz — 5 kW
5.0 MHz — 10 kW
10 MHz — 10 kW
15 MHz — 10 kW
UT 1 Corrections
For Additional Information Contact
NBS Radio Station WWVH
P.O. Box 417
Kekaha, Kauai, HI 90762
(808) 336-4361
SCD Time Code On 100 Hz Subcarrier


00
600 Hz Tone
45
UTC Voice Announcement
52.5
Silent Except Tick
60
00
Special Announcement Or 500 Hz Tone
45
52.5
Silent Except Tick
60
UTC Voice Announcement
Seconds

- Beginning of each hour is identified by 0.8-second long, 1500-Hz tone.
- Beginning of each minute is identified by 0.8-second long, 1200-Hz tone.
- The 29th & 59th second pulse of each minute is omitted.

RECEIVERS
UNIT VII

JOB SHEET #1 — IDENTIFY THE STAGES IN AN AM RECEIVER AND ON ITS ASSOCIATED SCHEMATIC DIAGRAM

A. Equipment and materials needed

1. Appropriate AM receiver
2. Schematic diagram of the receiver

   (NOTE TO INSTRUCTOR: The student will be required to write on the schematic.)

B. Procedure

1. Remove case from radio receiver.
2. Locate the power supply section on the receiver schematic.
3. Draw a line around the power supply section on the receiver schematic diagram.
4. Locate the components of the power supply in the receiver unit.
5. Locate the audio amplifier (power amplifier) on the receiver schematic.
6. Draw a line around the audio amplifier section on the receiver schematic diagram.
7. Locate the components of the audio amplifier in the receiver unit.
8. Locate the detector on the receiver schematic.
9. Draw a line around the detector section on the receiver schematic diagram.
10. Locate the components of the detector in the receiver unit.
11. Locate the mixer and local oscillator (or converter) section on the receiver schematic.
12. Draw a line around the mixer and local oscillator (or converter) section on the receiver schematic diagram.
13. Locate the components of the mixer and local oscillator (or converter) in the receiver unit.
14. Locate the IF amplifier section on the receiver schematic.
15. Draw a line around the IF amplifier section on the receiver schematic diagram.

JOB SHEET #1

16. Locate the components of the IF amplifier section in the receiver unit.
17. Locate the antenna in the receiver unit.
18. Trace the path of the AGC/AVC circuit on the schematic diagram.
19. Check with your instructor to determine if you have correctly identified the stages in the receiver.
20. Replace case on radio receiver.
21. Return the receiver to its proper storage location.

RECEIVERS
UNIT VII

JOB SHEET #2 — IDENTIFY THE STAGES IN AN FM RECEIVER AND ON ITS ASSOCIATED SCHEMATIC DIAGRAM

A. Equipment and materials needed

1. Appropriate FM receiver

2. Schematic diagram of the receiver

   (NOTE TO INSTRUCTOR: The student will be required to write on the schematic.)

B. Procedure

1. Remove case from radio receiver.
2. Locate the power supply section on the receiver schematic.
3. Draw a line around the power supply section on the receiver schematic diagram.
4. Locate the components of the power supply in the receiver unit.
5. Locate the audio amplifier (power amplifier) on the receiver schematic.
6. Draw a line around the audio amplifier section on the receiver schematic diagram.
7. Locate the components of the audio amplifier in the receiver unit.
8. Locate the discriminator/demodulator on the receiver schematic.
9. Draw a line around the discriminator/demodulator section on the receiver schematic diagram.
10. Locate the components of the discriminator/demodulator in the receiver unit.
11. Locate the mixer and local oscillator section on the receiver schematic.
12. Draw a line around the mixer and local oscillator section on the receiver schematic diagram.
13. Locate the components of the mixer and local oscillator in the receiver unit.
14. Locate the IF amplifier section on the receiver schematic.
15. Draw a line around the IF amplifier section on the receiver schematic diagram.

JOB SHEET #2

16. Locate the components of the IF amplifier section in the receiver unit.

17. Locate the limiter section on the receiver schematic.

18. Draw a line around the limiter section on the receiver schematic diagram.

19. Locate the limiter section in the receiver unit.

20. Locate the antenna in the receiver unit.

21. Trace the path of the AFC circuit on the schematic diagram.

22. Check with your instructor to determine if you have correctly identified the stages in the receiver.

23. Replace case on radio receiver.

24. Return the receiver to its proper storage location.

RECEIVERS
UNIT VII

JOB SHEET #3 — TUNE IN AND ANALYZE TIME TONES

A. Equipment and materials needed

1. Receiver, capable of receiving frequencies from 2.5 MHZ to 20 MHZ
2. TM 4 and TM 5 showing NBS information (dependent upon instructor)
3. Clock or stopwatch

B. Procedure

1. Turn on receiver and allow to warm up.
2. Tune in an NBS station.

   (NOTE: It may be necessary to check each frequency as one frequency from each transmitting station should be receivable at all hours of the day.)

3. Listen to the tones and become familiar with the specific transmit signal being received.

   a) Which transmitter are you monitoring?____________

   b) Is the broadcaster a male or female?____________

   c) How many seconds before the minute does the announcement occur?

   ____

   d) Do the above features indicate the transmitter you specified in step 3a?

   ____

4. Show your results to the instructor.
5. Return all equipment and materials to their proper storage location.

RECEIVERS
UNIT VII

JOB SHEET #4 — TUNE IN AND ANALYZE FREQUENCY TONES

A. Equipment and materials needed

1. Receiver, capable of receiving frequencies from 2.5 MHZ to 20 MHZ
2. Oscilloscope, dual trace
3. Frequency counter
4. Various test leads
5. Transparencies 4 and 5 showing NBS information (dependent upon instructor)
6. Signal generator

B. Procedure

1. Turn on receiver and allow to warm up.
2. Tune in on NBS station. (2.5, 5, 10, 15, or 20 MZ carrier)
3. Generate a frequency (i.e. 10 KHZ) with approximately an equal amplitude signal.
4. Connect this signal to the receiver.

   (NOTE: The difference in frequencies appear as an output signal that will waver in amplitude at a specific frequency.)

5. Note the difference between the NBS carrier frequency and the oscillator frequency which is the output frequency.

   (NOTE: The waver frequency should be the difference between the oscillator frequency and the NBS carrier frequency.)

6. Check with your instructor for other frequency measurements.
7. When completed, show your results to the instructor.
8. Return all equipment and materials to their proper storage location.

RECEIVERS
UNIT VII

JOB SHEET #1 PRACTICAL TEST — IDENTIFY THE STAGES IN AN AM RECEIVER AND ON ITS ASSOCIATED SCHEMATIC DIAGRAM

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Drew a line around the power supply section on schematic.	______	______
3. Drew a line around the audio amplifier section on schematic.	______	______
4. Drew a line around the detector section on schematic.	______	______
5. Drew a line around the local oscillator and mixer (or converter) section on schematic.	______	______
6. Drew a line around the IF amplifier section on the schematic.	______	______
7. Traced path of AGC/AVC circuit on the schematic.	______	______
8. Identified the major components of receiver sections in the receiver unit as asked by the instructor.	______	______
9. Checked in/put away tools and materials.	______	______
10. Cleaned the work area.	______	______
11. Used proper tools correctly.	______	______
12. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
13. Practiced safety rules throughout procedure.	______	______
14. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Properly removed case from radio receiver	4	3	2	1
Located proper schematic diagram	4	3	2	1
Correctly replaced case on receiver	4	3	2	1
Correctly located stages in receiver	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

RECEIVERS
UNIT VII

JOB SHEET #2 PRACTICAL TEST — IDENTIFY THE STAGES IN AN FM RECEIVER AND ON ITS ASSOCIATED SCHEMATIC DIAGRAM

STUDENT'S NAME ______________________ DATE ____________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Drew a line around the audio amplifier section on schematic.	______	______
3. Drew a line around the discriminator section on schematic.	______	______
4. Drew a line around the local oscillator and mixer section on schematic.	______	______
5. Drew a line around the IF amplifier section on the schematic.	______	______
6. Drew a line around the limiter section on the schematic.	______	______
7. Traced path of AFC circuit on the schematic.	______	______
8. Identified the major components of receiver sections in the receiver unit as asked by the instructor.	______	______
9. Checked in/put away tools and materials.	______	______
10. Cleaned the work area.	______	______
11. Used proper tools correctly.	______	______
12. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
13. Practiced safety rules throughout procedure.	______	______
14. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Properly removed case from radio receiver	4	3	2	1
Located proper schematic diagram	4	3	2	1
Correctly replaced case on receiver	4	3	2	1
Correctly located stages in receiver	4	3	2	1

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

RECEIVERS
UNIT VII

JOB SHEET #3 PRACTICAL TEST — TUNE IN AND ANALYZE TIME TONES

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Correctly tuned in the NBS frequency.	______	______
3. Correctly determined the transmitter signal received.	______	______
4. Correctly measured the tones as they occurred.	______	______
5. Checked in/put away tools and materials.	______	______
6. Cleaned the work area.	______	______
7. Used proper tools correctly.	______	______
8. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
9. Practiced safety rules throughout procedure.	______	______
10. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #3 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Tuned NBS frequency	4	3	2	1
Identified receiver signal	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

RECEIVERS
UNIT VII

JOB SHEET #4 PRACTICAL TEST — TUNE IN AND ANALYZE FREQUENCY TONES

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Correctly tuned in the NBS frequency.	______	______
3. Correctly set up the second signal.	______	______
4. Properly measured the difference frequency.	______	______
5. Checked in/put away tools and materials.	______	______
6. Cleaned the work area.	______	______
7. Used proper tools correctly.	______	______
8. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
9. Practiced safety rules throughout procedure.	______	______
10. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #4 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:				
Tuned NBS frequency	4	3	2	1
Measured difference frequency	4	3	2	1

EVALUATOR'S COMMENTS: ____________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

RECEIVERS
UNIT VII

TEST

NAME ____________________ SCORE ____________________

1. Match the terms on the right with their correct definitions.

(NOTE: Answers continue on next page.)

_____a. An apparatus of electronic circuits that receives a signal and processes the signal into a recognizable form such as voice or data

_____b. An apparatus of electronic circuits designed to receive and process amplitude modulated signals

_____c. An apparatus of electronic circuits designed to receive and process frequency modulated signals

_____d. The ability of a receiver to select one signal and reject all others

_____e. The ability of a receiver to amplify a small signal

_____f. The stage in a receiver which produces an unmodulated variable RF frequency

_____g. The stage in a receiver which heterodynes the RF signal from the receiving antenna and the RF frequency generated by the local oscillator

_____h. Frequency that results from mixing an RF signal from the RF amplifier with the local oscillator RF frequency

_____i. The stage in a receiver that separates the intelligence signal from the IF frequency

_____j. Designed to insure constant amplitude

_____k. The electronic circuit in an FM receiver that separates the intelligence signal from the IF

1. AFC
2. AM receiver
3. AVC/AGC
4. Co-channel interference
5. Converter
6. Detector
7. Discriminator
8. Double conversion
9. FM receiver
10. IF
11. Image frequency
12. Image rejection ratio

TEST

______l. Two stage process of producing first one intermediate frequency followed by the production of a second intermediate frequency

______m. The process of producing a single intermediate frequency (IF) in a superheterodyne receiver

______n. An electronic circuit that automatically increases or decreases the gain of a receiver in an inverse relationship with the strength of the received signal

______o. An electronic circuit that assures a constant IF center frequency in an FM receiver by keeping the local oscillator frequency separated from the RF amplifier signal by a fixed amount

______p. Undesirable interference in an electronic signal

______q. A stage in a receiver that is a combination local oscillator and mixer

______r. Circuit for preventing a radio receiver from producing audio frequency output in the absence of the predetermined signal

______s. Interfering signal of the same frequency as the desired signal

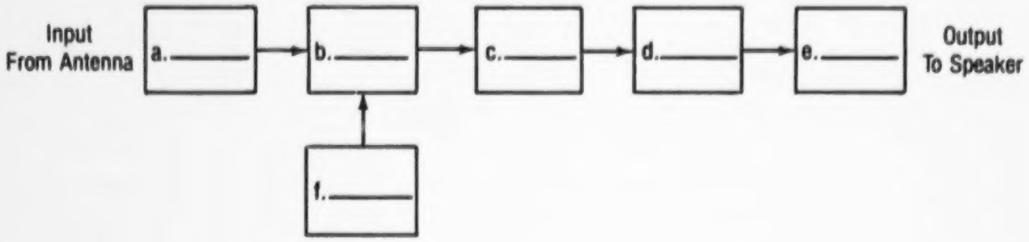
______t. An unwanted signal that arises from a source other than that to which the receiver is tuned, usually during heterodyning action in the mixer whose frequency falls within the bandpass of the IF amplifier

______u. The ratio of the desired signal amplitude to the image signal amplitude

13. Limiter
14. Local oscillator
15. Mixer
16. Noise
17. Receiver
18. Selectivity
19. Sensitivity
20. Single conversion
21. Squelch circuit

TEST

2. Match the stages in the AM superheterodyne receiver block diagram shown below with their correct names.



1. RF amplifier
2. Audio amplifier
3. Detector
4. Mixer
5. Local oscillator
6. IF amplifier

3. Complete the following statements concerning the functional characteristics of stages in an AM receiver by inserting the word(s) which best completes each statement.

   a. The RF amplifier stage and associated input circuitry allow it to ____________ the incoming RF signal.

   b. The RF amplifier ____________ the oscillator from the antenna preventing radiation from the receiver.

   c. The RF amplifier also isolates the mixer from the antenna improving the ____________ frequency rejection of the receiver.

   d. The ____________ ____________ produces a sine wave of a frequency which differs from the desired station frequency by an amount equal to the intermediate frequency.

   e. The ____________ heterodynes the carrier and sideband frequencies producing ten significant frequencies at its output.

   f. The IF amplifier amplifies the mixer output signal and applies it to the ____________ stage.

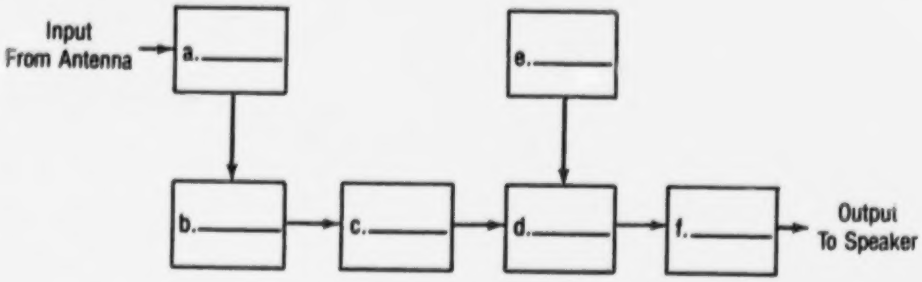
   g. IF amplifiers serve a major role in determining receiver ____________.

   h. The ____________ recovers the intelligence from the modulated wave.

   i. The audio amplifier increases the power of the ____________ signal to a level sufficient to drive the output device.

TEST

4. Match the stages in the single sideband receiver block diagram shown below with their correct names.



1. RF amplifier
2. Frequency converter
3. IF amplifier
4. Oscillator
5. Product detector
6. Audio amplifier

5. Complete the following statements concerning the functional characteristics of stages in an SSB receiver by inserting the word(s) which best completes each statement.

a. The frequency converter and IF amplifier in a single-sideband receiver have a bandwidth that is ____________-____________ that of an AM receiver that passes the same intelligence signal.

b. The function of the ____________, typically a product detector, is to remove the intelligence signal from the carrier.

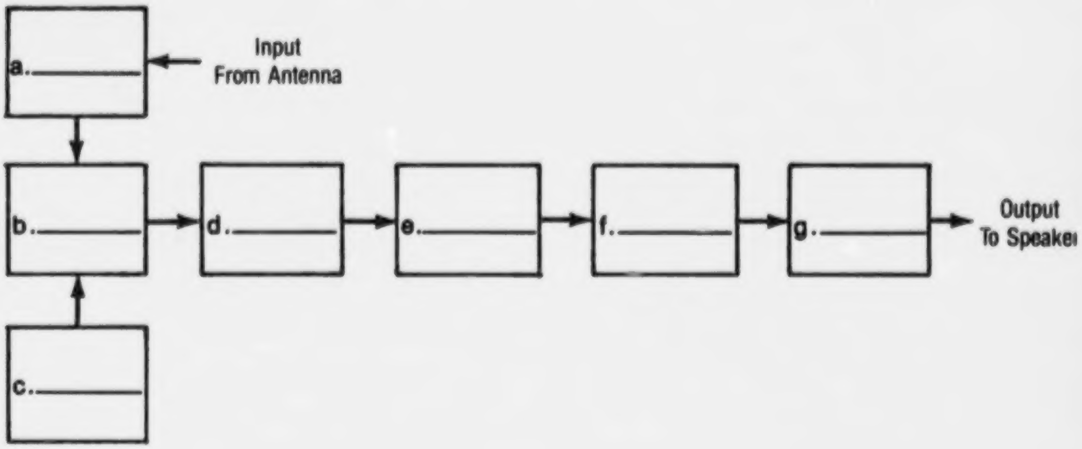
c. The ____________ frequency is supplied by a reference frequency oscillator.

d. The reference frequency oscillator generates the same frequency as the carrier oscillator in the ____________ .

e. The ____________ amplifier raises the level of the intelligence signal to that required to drive the output transducer.

TEST

6. Match the stages in the FM receiver block diagram shown below with their correct names.



1. Limiter
2. Mixer
3. Local oscillator
4. AF amplifier
5. RF amplifier
6. Discriminator
7. IF amplifier

7. Complete the following statements concerning the functional characteristics of stages in an FM receiver by inserting the word(s) which best completes each statement.

   a. The function of the RF amplifier is very similar to that in an AM receiver with the primary difference being the ______________ of operation and ______________.

   b. The function of the mixer stage is similar to that of the AM receiver except for the ______________ processed.

   c. The function of the ______________ stage in an FM receiver is to remove any amplitude variations that may be present in the IF signal.

   d. The ______________ produces an audio signal whose frequency is determined by the rate of frequency deviation, and whose amplitude is determined by the amount of deviation in the incoming frequency.

   e. The ______________ amplifier increases the demodulated signal to a power level sufficient to drive the output transducer.

TEST

8. Select true statements concerning the characteristics of double conversion receivers by placing an "X" in the blank(s) preceding the true statement(s).

    ______a. A double-conversion receiver is designed to take advantage of both low and high IF frequencies.

    ______b. Low IF frequency is used first for good image frequency rejection.

    ______c. High IF frequency provides for improved selectivity and improved gain characteristics.

9. Complete the following statements concerning the characteristics of AGC and AFC circuits by inserting the word(s) which best completes each statement.

    a. AGC is a circuit that automatically varies the gain of a receiver to maintain the ____________ at a constant level regardless of the strength of the input signal.

    b. An AGC circuit derives a DC feedback control voltage from the detected ____________ signal.

    c. The AGC voltage in AM receivers is used to automatically vary the ____________ and therefore the gain of the RF and IF ampliers.

    d. Automatic ____________ control circuits in FM receivers use a feedback system to develop a DC control voltage to be applied to the oscillator to compensate for changes in the oscillator frequency.

10. Select true statements concerning specifications for receivers by placing an "X" in the blanks preceding the true statements.

    ______a. Dynamic range is the measure of the amplitude of the weakest signal that can be received without it being obliterated by noise and is specified as the signal-to-ratio of the receiver

    ______b. Selectivity is the measure of the receiver's ability to select the desired frequency and reject all other frequencies.

    ______c. Image reaction is the measure of the receiver's ability to reject a strong signal at the exact image frequency.

    ______d. Sensitivity is a measure of the ability of a receiver to receive both very weak signals and very strong signals without introducing distortion in either.

TEST

11. Distinguish between WWV and WWVH frequency standards by placing "WWV" or "WWVH" in the appropriate blanks.

(NOTE: Some characteristics may apply to both.)

_____a. Transmitted on frequencies of 2.5, 5, 10, 15, and 20 MHz

_____b. The announcement occurs 15 seconds before the minute

_____c. Broadcasts a female voice

_____d. The beginning of each minute is identified by an 800 m sec 1.2 KHz tone

_____e. Each alternate minute a 500 or 600 Hz tone is broadcast

_____f. Broadcasts a male voice

_____g. A 440 Hz tone is broadcast as a marker for chart recorders and other automated electronic equipement

_____h. Each second, except the 29th and 59th, a 5 m sec pulse of 1 KHz is transmitted

_____i. The announcement occurs 7.5 seconds before the minute

_____j. The beginning of each minute is identified by an 800 m sec 1KHz tone

_____k. The beginning of each hour is identified by an 800 m sec 1.5 KHz tone

_____l. Transmitted on frequencies of 2.5, 5, 10, and 15 MHz

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

12. Demonstrate the ability to:

   a. Identify the stages in an AM receiver and on its associated schematic. (Job Sheet #1)

   b. Identify the stages in an FM receiver and on its associated schematic. (Job Sheet #2)

   c. Tune in and analyze time tones. (Job Sheet #3)

   d. Tune in and analyze frequency tones. (Job Sheet #4)

RECEIVERS
UNIT VII

ANSWERS TO TEST

1. a. 17
   b. 2
   c. 9
   d. 18
   e. 19
   f. 14
   g. 15
   h. 10
   i. 6
   j. 13
   k. 7
   l. 8
   m. 20
   n. 3
   o. 1
   p. 16
   q. 5
   r. 21
   s. 4
   t. 11
   u. 12

2. a. 1
   b. 4
   c. 6
   d. 3
   e. 2
   f. 5

3. a. Amplify
   b. Isolates
   c. Image
   d. Local oscillator
   e. Mixer
   f. Detector
   g. Selectivity
   h. Detector
   i. Intelligence (audio)

4. a. 1
   b. 2
   c. 3
   d. 5
   e. 4
   f. 6

5. a. One-half
   b. Demodulator
   c. Reference
   d. Transmitter
   e. Audio

ANSWERS TO TEST

6. a. 5
   b. 2
   c. 3
   d. 7
   e. 1
   f. 6
   g. 4

7. a. Frequency, bandwidth
   b. Frequencies
   c. Limiter
   d. Demodulator
   e. Audio

8. a

9. a. Volume
   b. Intelligence
   c. Bias
   d. Frequency

10. b, c

11. a. WWV
    b. WWVH
    c. WWVH
    d. WWVH
    e. WWV, WWVH
    f. WWV
    g. WWV, WWVH
    h. WWV, WWVH
    i. WWV
    j. WWV
    k. WWVH
    l. WWVH

12. Performance skills evaluated to the satisfaction of the instructor

TRANSMITTERS
UNIT VIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to analyze waveforms in AM and FM transmitters, calculate percentage of modulation, and perform fundamental transmitter measurements. Competencies will be demonstrated by completing the assignment sheets, job sheet, and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to transmitters with their correct definitions.
2. List three major components of an electronic communications system.
3. Explain the purpose of major transmitter stages.
4. Complete statements concerning the characteristics of standard AM transmitters.
5. Complete statements concerning the characteristics of double-sideband suppressed-carrier transmitters.
6. Complete statements concerning the characteristics of single-sideband transmitters.
7. Select true statements concerning characteristics of FM transmitters.
8. List five transmitter measurements.
9. Identify stages in an AM transmitter. (Assignment Sheet #1)

OBJECTIVE SHEET

10. Identify stages in an FM transmitter. (Assignment Sheet #2)

11. Demonstrate the ability to construct a simple AM transmitter and analyze transmitter waveforms. (Job Sheet #1)

TRANSMITTERS
UNIT VIII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet and assignment sheets.

F. Discuss information sheet and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheet.

H. Discuss and demonstrate the procedures outlined in the job sheet.

I. Integrate the following activities throughout the teaching of this unit:

1. Demonstrate the operation of AM and FM transmitters.
2. Demonstrate transmitter measurements.
3. Demonstrate transmitter alignment procedures.
4. Review federal regulations.
5. Tour transmitter sites such as local TV and radio stations or federal installations where permitted.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN WRITING THIS UNIT

A. *Electronic Communications*. Benton Harbor, MI: Heath Company, 1981.

B. Hardy, James K. *Electronic Communications Technology*. Englewood Cliffs, NJ: Prentice-Hall, 1986.

C. Kennedy, George. *Electronic Communication Systems*. Third Edition. New York: McGraw-Hill Book Company, 1985.

D. Schrader, Robert L. *Electronic Communication*. Fifth Edition. New York: McGraw-Hill Book Company, 1985.

E. Miller, Gary M. *Modern Electronic Communication*. Third Edition. Englewood Cliffs, NJ: Prentice-Hall, 1983.

F. Gerrish, Howard H. and Dugger, William E. *Electricity and Electronics*. South Holland, IL: Goodheart-Willcox Company, Inc., 1980.

TRANSMITTERS
UNIT VIII

INFORMATION SHEET

I. **Terms and definitions**

A. AM (amplitude modulation) — The process by which an electronic signal is used to vary the amplitude of an RF carrier

B. Antenna — A device used to radiate energy into space or receive energy from space

C. De-emphasis — Process used in the audio section of an FM receiver to attenuate high frequencies

D. Double-sideband transmission — Method of electronic communication in which the sideband frequencies produced by the process of modulation and the carrier frequency are all transmitted

E. DSBSC (Double-sideband suppressed-carrier) transmission — Method of electronic communication in which the sideband frequencies produced by the process of modulation are transmitted with the carrier being suppressed before transmission

F. FM (frequency modulation) — The process by which an electronic signal is used to vary the frequency of a higher frequency carrier

G. FM transmission — Method of electronic communication in which a constant amplitude carrier wave is transmitted that varies in frequency in direct proportion to the amplitude and frequency of a modulating waveform

H. High level modulation — Modulation produced at a point in a system where the power level approximates that at the output of the system such as collector modulation of the final RF amp

I. Low level modulation — Modulation produced at a point in a system where the power level is low compared with the power level at the output of the system

J. Multiplier — Circuit used to increase frequency to a multiple of the input frequency

K. Pre-emphasis — Process used to enhance or amplify high frequencies in an FM transmitter

L. SSB (Single-sideband suppressed-carrier) transmission — Method of electronic communication in which one of the sideband frequencies produced by the process of modulation is transmitted with the other sideband and carrier suppressed before transmission

INFORMATION SHEET

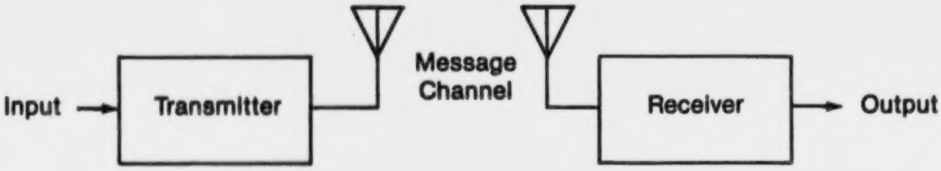
M. Telecommunications — The practice of the transfer of information by an electromagnetic means

N. Transmitter — A device, circuit, or apparatus used in a telecommunications system to originate an electrical signal that is to be transferred to another location

II. **Major components of an electronic communications system**

(NOTE: The basic purpose of an electronic communication system is to communicate information from one location to another by an electronic means.)

A. A basic block diagram of an electronic communications system consists of a transmitter, a message channel, and a receiver.


Input
Transmitter
Message Channel
Receiver
Output

B. The transmitter converts the information into an electronic signal.

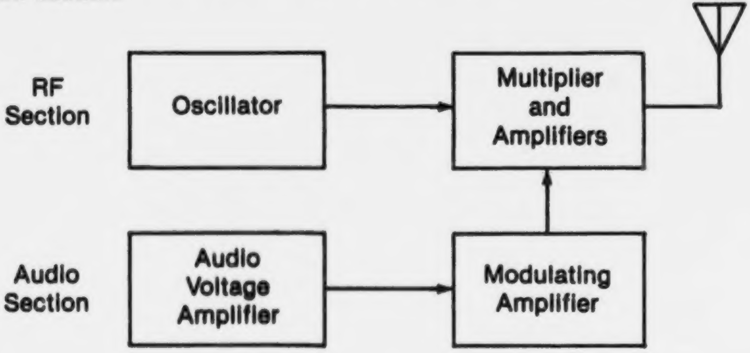
C. The message channel carries the electronic information from transmitter to receiver and may be a wire, fiber optic cable, electromagnetic wave, laser, air, or some other medium.

D. The receiver converts the information back into some intelligent form such as sound or a picture (video).

III. **Purpose of major transmitter stages**

A. The basic purpose of the transmitter is to process and encode the incoming intelligence so as to make it suitable for transmission.

B. A practical transmitter contains a radio frequency (RF) section and a modulation section.


RF Section
Oscillator
Multiplier and Amplifiers
Audio Section
Audio Voltage Amplifier
Modulating Amplifier

INFORMATION SHEET

C. The radio frequency section consists of an oscillator and amplifier that have the function of producing a carrier wave of the proper frequency and power to be transmitted.

D. The oscillator generates the RF carrier.

E. The amplifier has four functions it can perform.

  1. Function as a buffer to isolate the oscillator from the changing impedance of the antenna circuit
  2. Raise the frequency to some multiple of the oscillator frequency
  3. Function as a power amplifier
  4. Perform as a nonlinear device for modulation to produce the desired modulated waveform

(NOTE: The amplifier section may perform one, two, three, or all four of the functions in one or more stages.)

F. The modulation section of the transmitter usually consists of a microphone, voltage amplifiers, and power amplifiers.)

  1. The microphone converts sound waves into voltage changes.
  2. The voltage amplifier amplifies the voltage from the microphone.
  3. The modulating amplifier produces the proper level of signal power that is required to accomplish modulation.

IV. **Characteristics of standard AM transmitters** (Transparency 1)

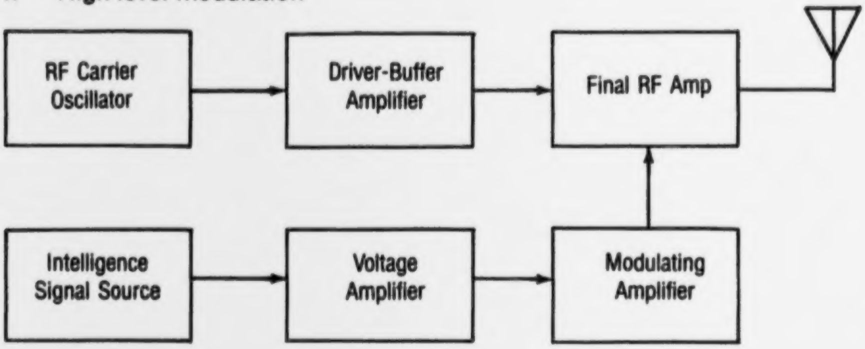
A. Amplitude modulated transmitters transmit a carrier wave in which the amplitude has been varied by a modulating signal containing intelligence.

  1. Carrier and two sidebands are transmitted
  2. Inexpensive transmitting and receiving equipment is a primary advantage
  3. Some uses of AM are broadcast and citizen band radio
  4. Three major disadvantages are:
    a. Most of the transmitted power is in the carrier.
    b. Bandwidth of the signal being transmitted is twice that of the intelligence being carried.
    c. Precise amplitude and phase relationships of sidebands and carrier must be maintained.
    d. These transmitters are susceptible to noise.

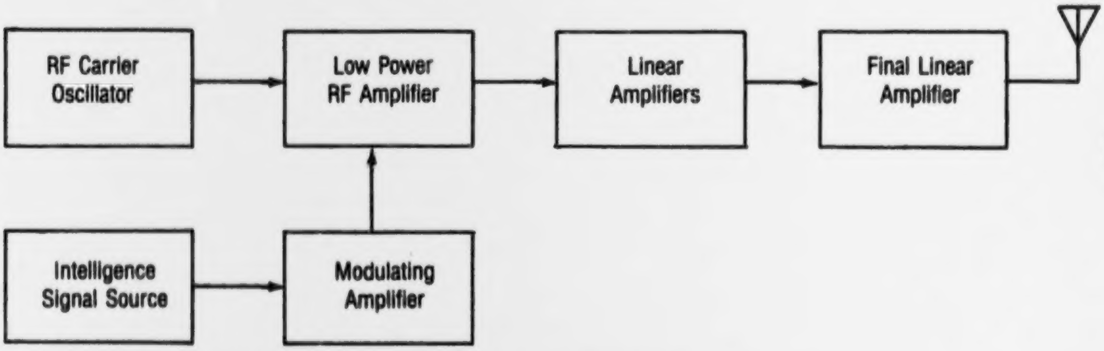
INFORMATION SHEET

B. The amplitude modulation process is accomplished by one of two methods:

1. High-level modulation


RF Carrier Oscillator
Driver-Buffer Amplifier
Final RF Amp
Intelligence Signal Source
Voltage Amplifier
Modulating Amplifier

2. Low-level modulation


RF Carrier Oscillator
Low Power RF Amplifier
Linear Amplifiers
Final Linear Amplifier
Intelligence Signal Source
Modulating Amplifier

C. The oscillator generates the RF carrier frequency.

1. Operates as class C amplifier with positive feedback
2. Crystal controlled for precise frequency stability
3. Supply voltage must be well filtered

D. The driver amplifier increases the power level of the RF carrier signal without changing its frequency.

1. Multiple driver stages may be used in some transmitters.
2. Provides isolation for oscillator circuit

E. The modulator amplifies the modulating signal (intelligence) to the proper power level required to accomplish modulation.

INFORMATION SHEET

F. The final RF power amplifier increases the power level of the carrier frequency.

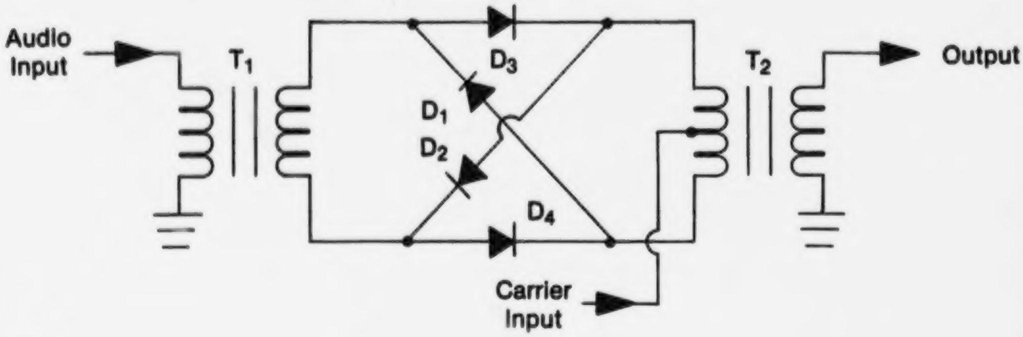
1. High level modulator operates class C
2. Low level modulator operates class A
3. An output filter network removes the unwanted harmonics generated by Class-C operation
4. The output network also provides impedance matching to the antenna

V. Characteristics of double-sideband suppressed-carrier (DSBSC) transmitters

A. DSBSC transmitters remove the carrier frequency and transmit only the sidebands.

B. Transmitter efficiency is an acquired advantage because two-thirds of power in standard AM is in the carrier.

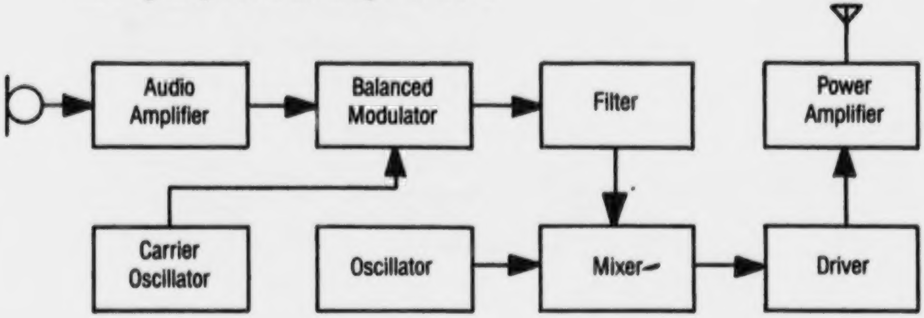
C. Elimination of the carrier is usually accomplished by incorporating a double-balanced modulator such as the ring modulator.



INFORMATION SHEET

VI. Characteristics of single-sideband (SSB) transmitters

A. Single-sideband transmitters suppress the carrier and one sideband transmitting only the remaining sideband.



B. Crystal controlled oscillator produces a stable frequency for generation of the carrier.

C. Balanced modulator is used to combine the intelligence signal with the carrier to produce the desired sidebands.

1. Operational characteristics of balanced modulator eliminate the carrier.

2. Both upper and lower sidebands are produced by the modulator.

D. The filter may be LC, crystal, or mechanical type.

1. Classified as bandpass filter

2. Removes the unwanted sideband

E. The mixer is a heterodyning stage that combines the single sideband with RF oscillations of a higher frequency.

(NOTE: The original single sideband is usually developed using a carrier frequency much lower than the transmitted frequency. Therefore, the sideband must be raised in frequency for transmission.)

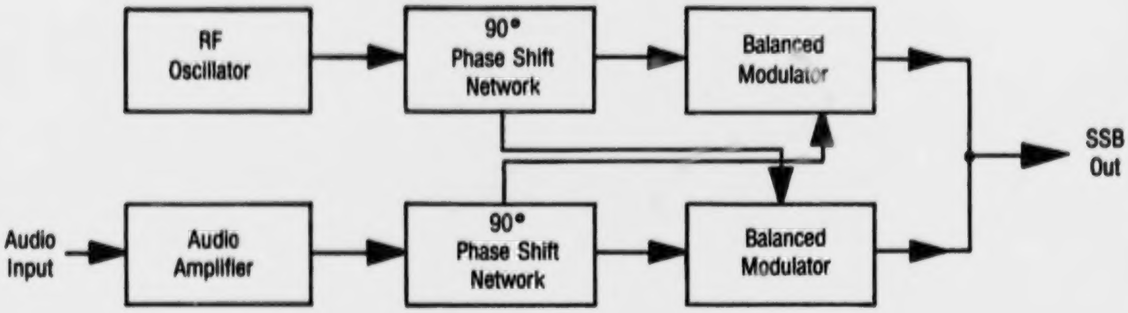
1. Sum and difference frequencies are produced by the heterodyning action.

2. A tuned circuit at the mixer output develops the desired frequency and couples it to the driver stage.

F. The driver and power amplifier are tuned linear amplifiers to assure the amplification of only the desired band of frequencies.

INFORMATION SHEET

G. SSB may also be created using a phasing method.


RF Oscillator
90° Phase Shift Network
Balanced Modulator
SSB Out
Audio Input
Audio Amplifier
90° Phase Shift Network
Balanced Modulator

1. Phase shift networks shift the phase of the audio signal and the RF signal 90 degrees before application to balanced modulators.
2. Phase shift reinforces one sideband and cancels the other at the output of the modulators.

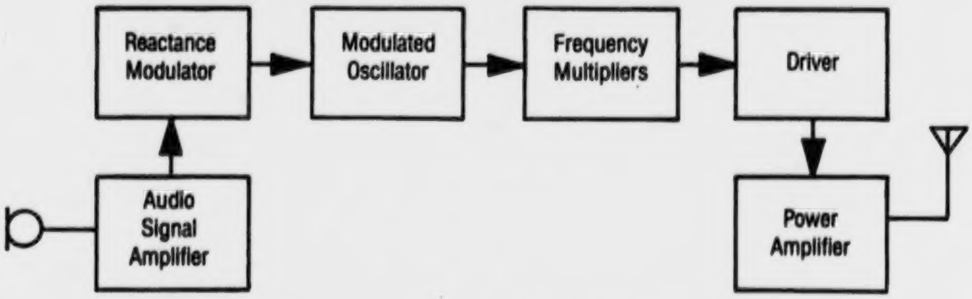
H. SSB transmitters use only half the space in the frequency spectrum as double-sideband transmission.

I. SSB is subject to less interference.

J. SSB is used primarily for voice communications.

VII. **Charcteristics of FM transmitters** (Transparency 2)

A. FM transmitters produce a constant amplitude output with a frequency that varies in proportion to the amplitude of the intelligence signal.


Reactance Modulator
Modulated Oscillator
Frequency Multipliers
Driver
Audio Signal Amplifier
Power Amplifier

B. The audio amplifier increases the audio signal to a level sufficient to drive the modulator.

(NOTE: The pre-emphasis network increases or emphasizes the higher frequencies. This improves the signal-to-noise ratio of the communication system. De-emphasis is employed in the receiver to restore relative strengths of the audio signal.)

INFORMATION SHEET

C. The modulator converts the audio signal into variations in reactance that is applied to oscillator circuit to cause changes in frequency that is proportional to the audio signal.

D. The oscillator generates a center frequency carrier waveform that deviates in accordance with the modulating signal.

   1. The amount of deviation from the center frequency is determined by the amplitude of the modulating audio signal.

   2. The rate of deviation is determined by the frequency of the modulating audio signal.

   (NOTE: The oscillator center frequency is usually lower in frequency than the broadcast carrier frequency.)

E. Frequency multipliers are used to raise the frequency of the oscillator to the frequency needed for transmission.

   1. Usually operated Class-C eliminating amplitude variations and generating harmonics

   2. Tuned circuits select harmonic of fundamental frequency

F. The driver is an intermediate amplifier used to develop the power necessary to drive the power amplifier.

G. The power amplifier is usually a heavy current device that increases the power of the RF carrier that is to be radiated by the antenna.

VIII. **Transmitter measurements**

A. A dummy load should be used to prevent signals from being transmitted that could interfere with communications of other users.

(NOTE: A transmitter should never be operated without a dummy load or antenna as damage to transmitter circuitry could occur.)

B. *Operating frequency checks* should be made with a high quality frequency counter to determine if the unit is operating legally and efficiently with the manufacturers' specifications and the federal requirements.

C. *Stray signal checks* (spurious emissions) should be made with a spectrum analyzer to determine if harmonics or nonrelated frequencies (spurious signals) are present.

D. *Modulation checks* may be made with an oscilloscope and/or spectrum analyzer to determine percentage of modulation and possible distortion in the transmitted signal.

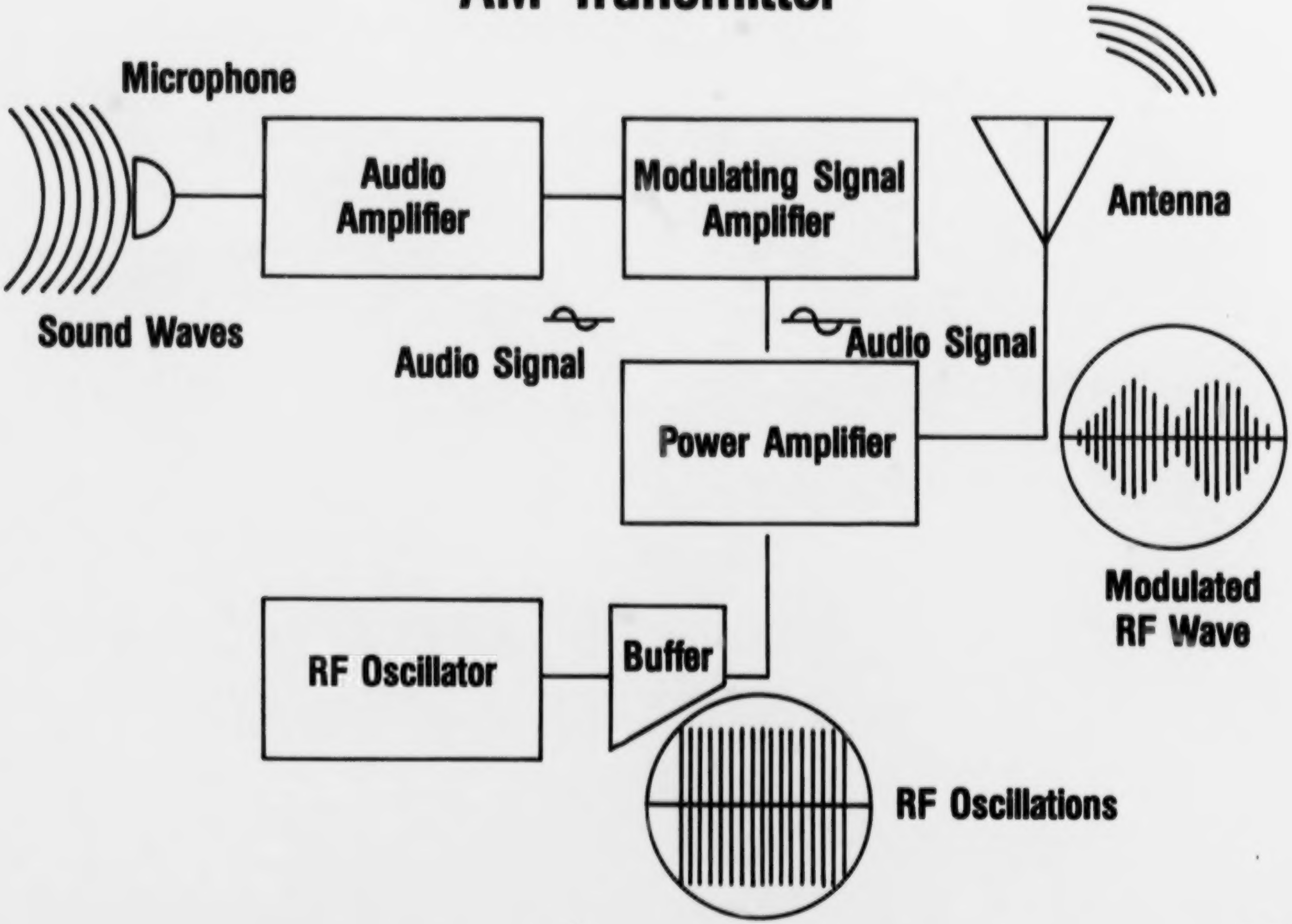
INFORMATION SHEET

E. *DC power input checks* are made to determine the DC power fed to the final RF amplifier from the power supply.

F. *RF power output measurements* are made to determine if the proper power is being delivered to the radiating antenna.

(NOTE: The method of making the checks may differ slightly depending upon the type of system, i.e. standard double-sideband AM, SSB, FM, etc.)

AM Transmitter



Microphone

Sound Waves

Audio Amplifier

Modulating Signal Amplifier

Audio Signal

Audio Signal

Antenna

Power Amplifier

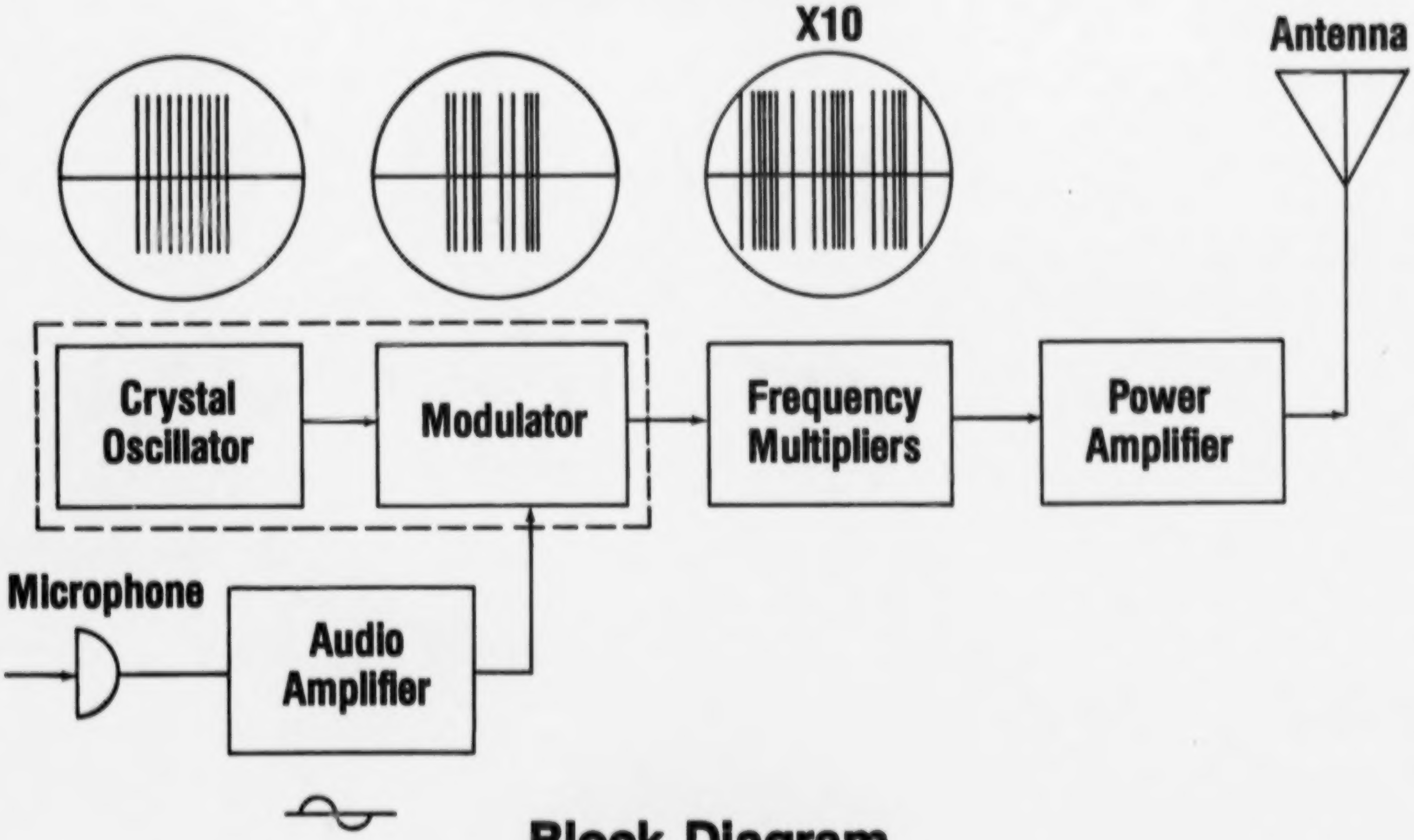
Modulated RF Wave

RF Oscillator

Buffer

RF Oscillations

FM Transmitter


X10
Antenna
Crystal Oscillator
Modulator
Frequency Multipliers
Power Amplifier
Microphone
Audio Amplifier

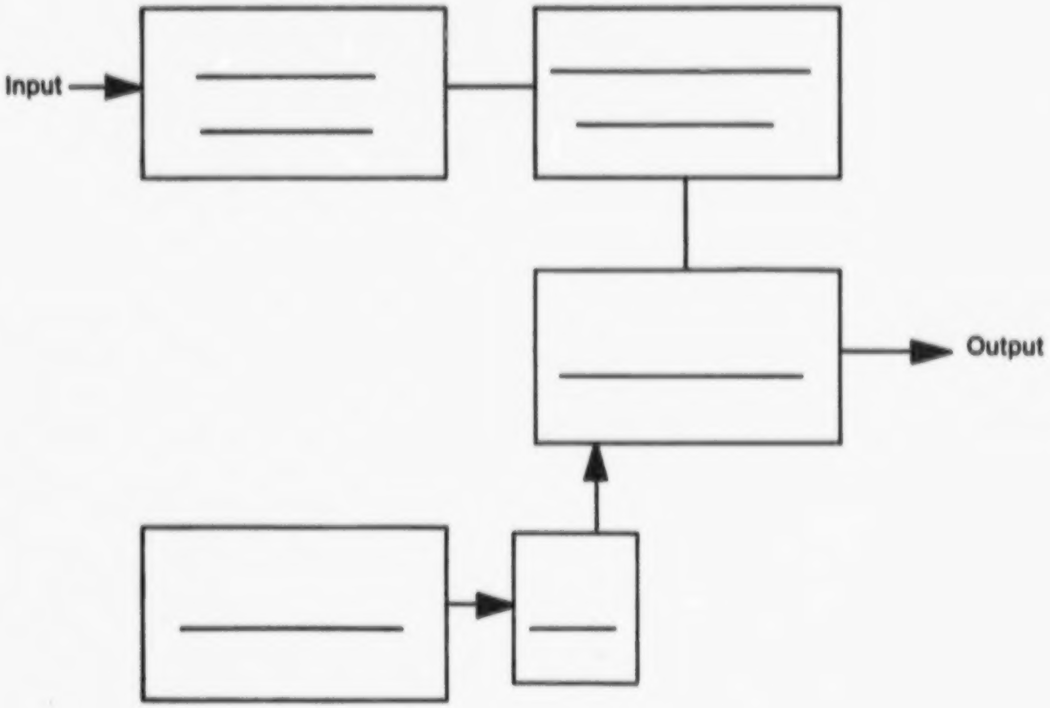
Block Diagram

TRANSMITTERS
UNIT VIII

ASSIGNMENT SHEET #1 — IDENTIFY STAGES IN AN AM TRANSMITTER

NAME ____________________ SCORE ____________________

Directions: Identify the stages in an AM transmitter by labeling the blocks in the transmitter block diagram with their correct names.

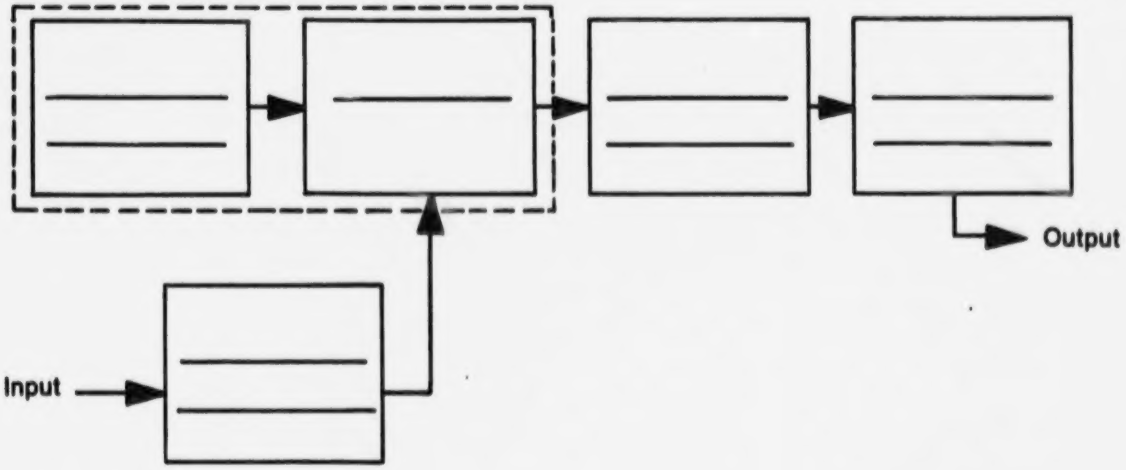


TRANSMITTERS
UNIT VIII

ASSIGNMENT SHEET #2 — IDENTIFY STAGES IN AN FM TRANSMITTER

NAME ____________________ SCORE ____________________

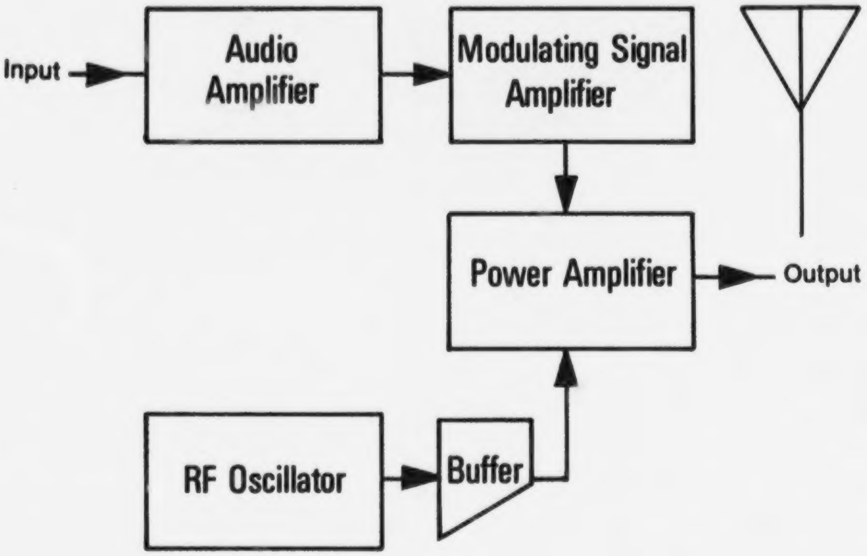
Directions: Identify the stages in an FM transmitter by labeling the blocks in the transmitter block diagram with their correct names.



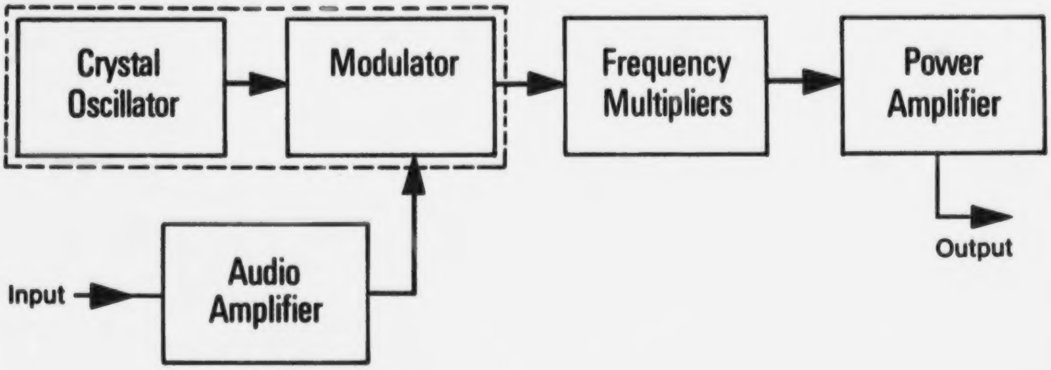
TRANSMITTERS
UNIT VIII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1


Input
Audio Amplifier
Modulating Signal Amplifier
Power Amplifier
Output
RF Oscillator
Buffer

Assignment Sheet #2


Crystal Oscillator
Modulator
Frequency Multipliers
Power Amplifier
Output
Input
Audio Amplifier

TRANSMITTERS
UNIT VIII

JOB SHEET #1 — CONSTRUCT A SIMPLE AM TRANSMITTER AND ANALYZE TRANSMITTER WAVEFORMS

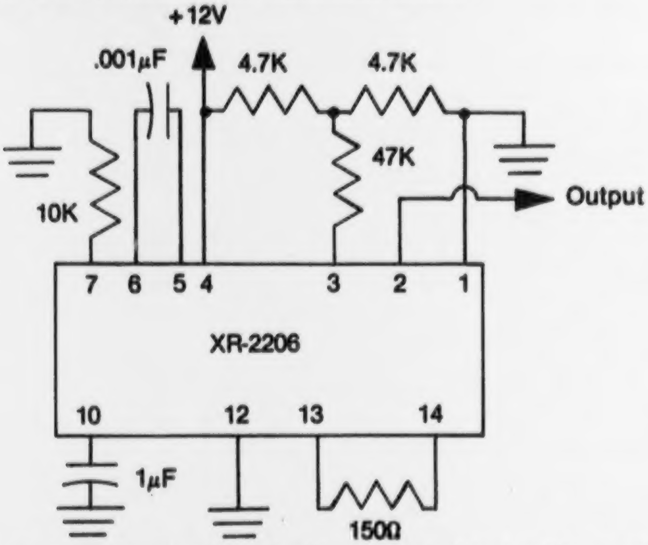
A. Equipment and materials needed

1. DC voltmeter
2. DC power supply
3. Sine wave or function generator
4. Oscilloscope and probe
5. XR-2206CP (or equivalent) integrated circuit
6. Two NPN transistors
7. 2 mH inductor
8. 22 μF capacitor
9. 10 μF capacitor
10. 1 μF capacitor
11. 0.1 μF capacitor
12. 0.0015 μF capacitor
13. 0.001 μF capacitor
14. 100 k resistor
15. 68 k resistor
16. 47 k resistor
17. 10 k resistor
18. 4.7 k resistor (2)
19. 150 ohm resistor
20. 100 K potentiometer

JOB SHEET #1

B. Procedure

1. Wire the circuit shown in the schematic below.



2. Adjust your oscilloscope's vertical input control to 1 volt/cm and the sweep control to 2 us/cm.

3. Turn on the power to the oscilloscope and connect it to the circuit output.

4. Attach the power supply to the circuit and adjust the power supply for an output of +12 VDC.

5. Adjust the oscilloscope controls for a stable display and observe the output waveform. What type of waveform appears at the output? ____________

6. Measure the period of the output waveform.

   Period = ____________

7. Calculate the frequency of the waveform.

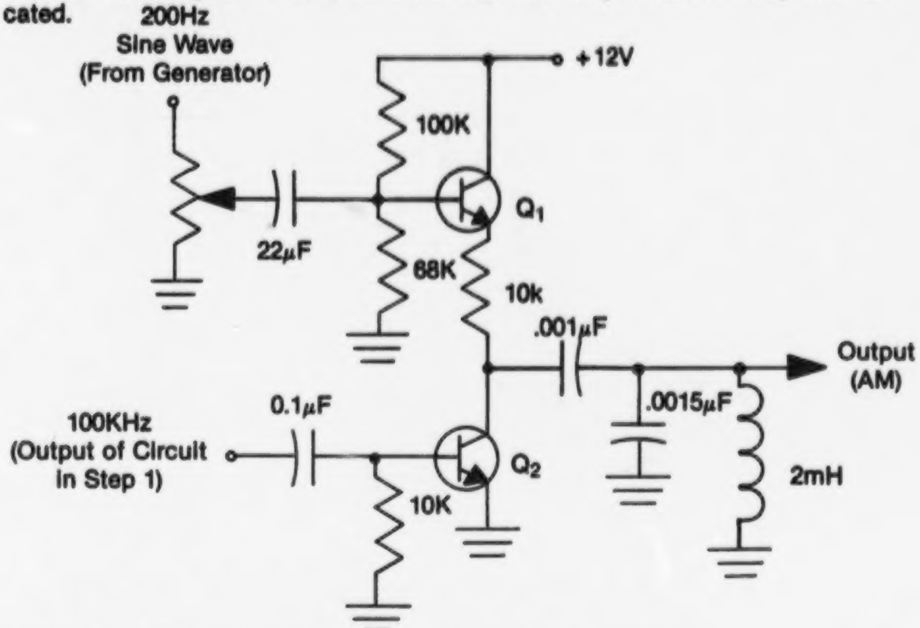
   Frequency = ____________

   (NOTE: You have just constructed the oscillator portion of the transmitter. The circuit to follow is a series modulator.)

8. Turn off the power to the circuit. Do not dismantle the circuit.

JOB SHEET #1

9. Wire the following circuit and connect it to the circuit you wired in step 1 as indicated.


200Hz
Sine Wave
(From Generator)
+12V
100K
Q_1
22µF
68K
10k
.001µF
Output
(AM)
0.1µF
100KHz
(Output of Circuit
in Step 1)
Q_2
.0015µF
2mH
10K

10. Connect the sine wave generator to the circuit as indicated.

11. Connect the oscilloscope to the AM output.

12. Turn on the power to the circuit.

13. Adjust the sine wave generator and R1 for maximum modulation of the output.

    (NOTE: 100% modulation is not obtainable with this simple circuitry due to the RF amplifier transistors' junction capacitance.)

14. Measure the percent of modulation.

    % modulation = ____________

15. Vary the amplitude and frequency of the modulating signal and observe the effects.

16. Turn off the power to the equipment.

17. Disassemble the circuit.

18. Return equipment and materials to their proper storage location.

TRANSMITTERS
UNIT VIII

JOB SHEET #1 PRACTICAL TEST — CONSTRUCT A SIMPLE AM TRANSMITTER AND ANALYZE TRANSMITTER WAVEFORMS

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Properly constructed the oscillator circuit according to the schematic diagram.	______	______
3. Set the oscilloscope for proper operation.	______	______
4. Properly connected the oscilloscope to the circuit.	______	______
5. Connected power supply to circuit and set output correctly.	______	______
6. Properly constructed the modulator circuit.	______	______
7. Properly connected series modulator circuit to oscillator circuit.	______	______
8. Properly connected the AM generator to the circuit.	______	______
9. Adjusted the AM generator to the circuit.	______	______
10. Obtained satisfactory waveforms.	______	______
11. Checked in/put away tools and materials.	______	______
12. Cleaned the work area.	______	______
13. Used proper tools correctly.	______	______
14. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
15. Practiced safety rules throughout procedure.	______	______
16. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Oscillator circuit	Wired correctly			Wired incorrectly
	4	3	2	1
Series modulator circuit	Wired correctly			Wired incorrectly
	4	3	2	1
% Modulation	Measured correctly			Measured incorrectly

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TRANSMITTERS
UNIT VIII

TEST

NAME ______________________ SCORE ______________________

1. Match the terms on the right with their correct definitions.

(NOTE: Definitions continue on next page.)

_____a. A device, circuit, or apparatus used in a telecommunications system to originate an electrical signal that is to be transferred to another location

_____b. The practice of the transfer of information by an electromagnetic means

_____c. A device used to radiate energy into space or receive energy from space

_____d. Modulation produced at a point in a system where the power level approximates that at the output of the system such as collector modulation of the final RF amp

_____e. Process used in the audio section of an FM receiver to attenuate high frequencies

_____f. Modulation produced at a point in a system where the power level is low compared with the power level at the output of the system

_____g. Method of electronic communication in which the sideband frequencies produced by the process of modulation and the carrier frequency are all transmitted

_____h. Process used to enhance or amplify high frequencies in an FM transmitter

_____i. Method of electronic communication in which the sideband frequencies produced by the process of modulation are transmitted with the carrier being suppressed before transmission

_____j. Method of electronic communication in which one of the sideband frequencies produced by the process of modulation is transmitted with the other sideband and carrier suppressed before transmission

1. Amplitude modulation
2. Antenna
3. De-emphasis
4. Double-sideband transmission
5. DSBSC transmission
6. Frequency modulation
7. FM transmission
8. High level modulation
9. Low level modulation
10. Multiplier
11. Pre-emphasis
12. SSB transmission
13. Telecommunications
14. Transmitter

TEST

_____k. Circuit used to increase frequency to a multiple of the input frequency

_____l. Method of electronic communication in which a constant amplitude carrier wave is transmitted that varies in frequency in direct proportion to the amplitude and frequency of a modulating waveform

_____m. The process by which an electronic signal is used to vary the amplitude of an RF carrier

_____n. The process by which an electronic signal is used to vary the frequency of a higher frequency carrier

2. List the three major components of an electronic communication system.

a. ____

b. ____

c. ____

3. Explain the purpose of each of the following major transmitter stages.

a, The oscillator — ____

____

____

b. The RF power amplifier — ____

____

____

c. Audio voltage amplifier — ____

____

____

d. Modulating amplifier — ____

____

____

TEST

4. Complete the following statements concerning the characteristics of standard AM transmitters by inserting the word(s) which best completes each statement.

   a. Amplitude modulated transmitters transmit a carrier wave in which the ____________ has been varied by a modulating signal containing intelligence.

   b. Amplitude modulated transmitters transmit a ____________ and two ____________.

   c. In standard AM transmitters three major disadvantages are:

      1. Most of the transmitted power is in the ____________

      2. Bandwidth of the signal being transmitted is ____________ that of the intelligence being carried

      3. Precise ____________ and ____________ relationships of sidebands and carrier must be maintained

   d. The amplitude modulation process is accomplished by one of two methods, ____________ modulation or ____________ modulation.

   e. The ____________ stage in an AM transmitter generates the RF carrier frequency.

   f. The ____________ amplifier increases the power level of the RF carrier signal without changing its frequency.

   g. The ____________ amplifies the modulating signal (intelligence) to the proper power level required to accomplish modulation.

   h. The final power RF amplifier increases the power level of the RF ____________.

   i. The final RF power amplifier is usually operated Class ____________.

   j. The output filter network removes the unwanted ____________ that are generated by Class-C operation of the final RF power amplifier.

TEST

5. Complete the following statements concerning the characteristics of double-sideband suppressed-carrier transmitters by inserting the word(s) that best completes each statement.

   a. DSBSC transmitters remove the __________ frequency and transmit only the __________ .

   b. Transmitter efficiency is an acquired advantage because two-thirds of power in standard AM is in the __________ .

   c. Elimination of the __________ is usually accomplished by incorporating a double-balanced modulator such as the ring modulator.

6. Complete the following statements concerning the characteristics of single-sideband transmitters by inserting the word(s) which best completes each statement.

   a. __________ - __________ transmitters suppress the carrier and one sideband transmitting only the remaining sideband.

   b. Crystal controlled __________ produces a stable frequency for generation of the carrier.

   c. Balanced modulator is used to combine the __________ signal with the __________ to produce the desired sidebands.

   d. The filter may be LC, crystal, or mechanical type and is classified as a __________ filter.

   e. The __________ is a heterodyning stage that combines the single sideband with RF oscillations of a higher frequency.

   f. Sum and difference frequencies are produced by the __________ action in the mixer stage.

   g. The driver and power amplifier are __________ __________ amplifiers to assure the amplification of only the desired band of frequencies.

   h. SSB uses only __________ the space in the frequency spectrum as double-sideband transmission.

TEST

7. Select true statements concerning characteristics of FM transmitters by placing an "X" in the blanks preceding the true statements.

_____a. FM transmitters produce a constant amplitude output with a frequency that varies in proportion to the amplitude of the intelligence signal.

_____b. The audio amplifier increases the audio signal to a level sufficient to drive the modulator.

_____c. The modulator converts the audio signal into variations in reactance that is applied to oscillator circuit to cause changes in frequency that is proportional to the audio signal.

_____d. The modulator generates a center frequency carrier waveform that deviates in accordance with the modulating signal.

_____e. Frequency multipliers are used to raise the frequency of the oscillator to the frequency needed for transmission.

_____f. The power amplifier is an amplifier used to develop the power necessary to drive the modulator.

_____g. The power amplifier is usually a heavy current device that increases the power of the RF carrier that is to be radiated by the antenna.

8. List five transmitter measurements that must fall within manufacturers' specifications and federal requirements.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

9. Identify stages in an AM transmitter. (Assignment Sheet #1)

10. Identify stages in an FM transmitter. (Assignment Sheet #2)

11. Demonstrate the ability to construct a simple AM transmitter and analyze transmitter waveforms. (Job Sheet #1)

TRANSMITTERS
UNIT VIII

ANSWERS TO TEST

1. a. 14
   b. 13
   c. 2
   d. 8
   e. 3
   f. 9
   g. 4
   h. 11
   i. 5
   j. 12
   k. 10
   l. 7
   m. 1
   n. 6

2. a. Transmitter
   b. Message channel
   c. Receiver

3. a. The oscillator generates the RF carrier
   b. The RF power amplifier acts as a buffer, sometimes as a frequency multiplier, and as a non-linear amplifier for modulators
   c. Amplifies the input to a level useable by the modulating amplifier
   d. Modulating amplifier raised the audio signal to the proper power level to accomplish modulation

4. a. Amplitude
   b. Carrier, sidebands
   c. 1) Carrier
      2) Twice
      3) Amplitude, phase
   d. High-level, low-level
   e. Oscillator
   f. Driver
   g. Modulating
   h. Carrier
   i. C
   j. Harmonics

5. a. Carrier, sidebands
   b. Carrier
   c. Carrier

ANSWERS TO TEST

6. a. Single-sideband
   b. Oscillator
   c. Intelligence, carrier
   d. Bandpass
   e. Mixer
   f. Heterodyning
   g. Timed linear
   h. Half

7. a, b, e, g

8. Answers may be in any order

   a. Operating frequency
   b. Stray (spurious) signal check
   c. Modulation check
   d. DC power input check
   e. RF power output

9.-10. Evaluated to the satisfaction of the instructor

11. Performance skills evaluated to the satisfaction of the instructor

INTRODUCTION TO VIDEO
UNIT IX

UNIT OBJECTIVE

After completion of this unit, the student should be able to properly use an oscilloscope to view a video waveform and identify signal components within the video waveform. Competencies will be demonstrated by completing the job sheet and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to video with their correct definitions.
2. Name applications of television systems.
3. Complete a chart concerning selected standards of transmitted video signals.
4. Complete statements concerning elements of the television picture.
5. Name the four components within the composite color video signal.
6. Complete statements concerning the characteristics of color burst and synchronizing pulses.
7. List major stages in a color television receiver.
8. Match the stages in the RF tuner with their functions.
9. Complete statements concerning the characteristics and functions of the video IF amplifier.
10. Name the three major stages of the sound section and give their functions.

OBJECTIVE SHEET

11. Complete statements concerning the characteristics and functions of the video detector and video amplifiers.

12. Match terms related to the characteristics and functions of the chrominance section with their correct descriptions.

13. Complete statements concerning characteristics of the AGC and synchronization circuits.

14. Complete statements concerning the characteristics and functions of the deflection circuits.

15. Select true statements concerning standards for stereo sound in television broadcast.

16. Complete statements concerning general safety precautions for television service or repair.

17. Demonstrate the ability to view video waveforms. (Job Sheet #1)

INTRODUCTION TO VIDEO
UNIT IX

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheets.

F. Discuss information sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheet.

H. Discuss and demonstrate the procedures outlined in the job sheet.

I. Integrate the following activities throughout the teaching of this unit:

    1. Use a television to show elements of the television picture to students, then discuss these elements with them.
    2. Identify major carriers in local vicinity.
    3. Tour a television studio.
    4. Tour a television transmitter site.
    5. Visit a cable television receiving site.
    6. Stress the importance of observing safety precautions when working on a television or other electrical equipment.
    7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Administer test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Badrkhan, Kamarin S. *Video Systems: TV Principles and Servicing.* New York: John Wiley and Sons, 1986.

B. Kennedy, George. *Electronic Communication Systems.* Third Edition. New York: McGraw-Hill Book Company, 1985.

C. Schrader, Robert E. *Electronic Communication.* Fifth Edition. New York: McGraw-Hill Book Company, 1985.

INTRODUCTION TO VIDEO
UNIT IX

INFORMATION SHEET

I. **Terms and definitions**

A. Aural — Sound or audio

B. Chrominance signal — The color information within the composite video signal

C. Color burst — A waveform of short duration that contains phase and frequency reference information for color television circuits

D. Composite video — A whole that is a combination of two or more parts, i.e. a complete video signal consisting of luminance, chrominance, sync, blanking, and color burst

E. Diplexer — Coupling unit that provides for more than one transmitter to broadcast from the same antenna

F. Heterodyne — To combine or superimpose frequencies to obtain a different frequency

G. Luminance signal — The brightness information within a composite video signal

H. Picture element — A single light or dark element within a picture

I. Resolution — The fineness or detail within an image

J. Sideband — Frequencies on either side of carrier signal that are produced through modulation

K. Vestigial sideband — Small amount (vestige) that remains of a complete original sideband

L. Video — Picture portion of a television signal; signal that carries visual information

II. **Applications of television systems**

A. Commercial broadcast programming originates in numerous studio locations around the world.

1. Networked or relayed by microwave
2. Relayed worldwide by satellite

INFORMATION SHEET

B. Other forms of television programming, transmission, and reception are used for commercial, entertainment, and educational purposes.

1. Subscription television services
2. Community or building master-antenna systems (MATV)
3. Closed-circuit television systems (CCTV)
4. Cable television (CATV)
5. Computer system terminal-displays

III. Standards and characteristics of transmitted video signals

A. The NTSC standards approved by the Federal Communications Commission for commercial color television in 1953 were prepared by the National Television Standards Committee (NTSC), a committee responsible to the Electronics Industry Association (EIA).

B. The NTSC standards include video transmission standards and sound transmission standards.

1. Vestigial sideband amplitude modulations for video
2. Negative video modulation polarity
3. Interlace ratio of 2:1
4. Aspect ratio of 4:3
5. FM sound system

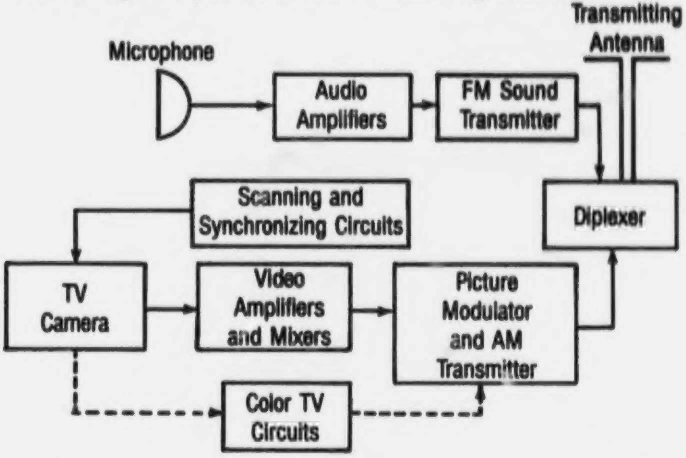
C. Additional selected standards that are helpful in understanding broadcast television are listed in the following chart:

Standard		
Number of lines per frame	525	
Number of frames per second	30	
Field frequency	60	Hz
Line frequency	15750	Hz
Channel width	6	MHz
Video bandwidth	4.2	MHz
Color subcarrier	3.58	MHz *
Maximum sound deviation	25	kHz
Intercarrier sound separation	4.5	MHz

* Precise frequency is 3.579545 MHz

INFORMATION SHEET

D. The television transmitter is essentially two transmitters with the outputs of each fed through a diplexer to the transmitting antenna.


Transmitting Antenna
Microphone
Audio Amplifiers
FM Sound Transmitter
Scanning and Synchronizing Circuits
Diplexer
TV Camera
Video Amplifiers and Mixers
Picture Modulator and AM Transmitter
Color TV Circuits

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IV. **Elements of the television picture**

A. Detail, resolution, and definition are terms which refer to sharpness or clarity of the picture.

1. These are related to number of picture elements.

2. Broadcast TV images have 483 lines of visible picture information with 540 picture elements per line.

B. Contrast is the difference in the brightness and darkness between adjacent colors or between adjacent shades of black, white, or gray.

C. Picture brightness is the average intensity or illumination of the image on the TV screen.

D. Color hue or tint refers to the dominant color.

E. Color saturation is the amount of color in an image (absence of white light).

F. Gamma is the relative contrast between the original scene and the image reproduced on the television screen.

INFORMATION SHEET

V. **Components of the composite color video signal** (Transparency 1)

   A. A complete colorplexed video composite signal (S signal) consists of the luminance signal (monochrome picture information), the chrominance signal (color picture information), synchronizing pulses, and a color burst signal.

   B. The luminance, or Y signal, is used to reproduce brightness and detail information.

      1. The luminance sideband signal may extend from 1.25 MHz below picture carrier frequency to 4.5 MHz above the picture carrier frequency.

      2. Fine detail of picture is located in upper sideband only.

   C. The chrominance signal does not produce a good viewable picture by itself.

      1. Information from chrominance signal is used to modulate a 3.579545 MHz (3.58 MHz) color subcarrier.

         (NOTE: The color subcarrier is suppressed at transmission.)

      2. I and Q signal modulation of the 3.58 MHz subcarrier is used to carry color information from transmitter to receiver via the modulated sidebands.

      3. The Q signal sideband contains color frequencies from 0 to 0.5 MHz.

      4. The I signal sideband contains frequencies from 0 to 1.5 MHz (circumstances limit the use of approximately 0.6 MHz of the upper I sideband.)

VI. **Characteristics of the color burst and synchronizing pulses**

   A. The color burst is generated at the studio and provides a frequency and phase reference and is propagated through the entire transmission network.

      1. In-phase with transmitter color subcarrier

      2. Serves as reference for a 3.58 MHz oscillator in the receiver

      3. Contains eight to eleven cycles of subcarrier frequency

      4. Combined in the receiver with I and Q sidebands to restore the complete color signal

      5. Located on the "back porch" of the horizontal blanking pulse

INFORMATION SHEET

B. Synchronizing pulses are transmitted as part of the total video signal.

(NOTE: Signal may appear inverted when viewed on an oscilloscope.)

1. The 15,750 Hz horizontal sync pulse has a duration of about 5.4 μs with the leading edges separated by 63.5 μs.
2. The 31,500 Hz equalizing pulses have a duration of about 2.7 μs each with the leading edges separated by 31.75 μs.
3. The 15,750 Hz horizontal blanking pulses have a duration of about 10 μs each.
4. The 60 Hz vertical blanking pulses have a duration of 830 to 1330 μs.

VII. **Stages in a color television receiver** (Transparency 2)

(NOTE: A color video receiver may be simplified into major signal processing blocks.)

A. RF tuner

B. Video IF amplifier

C. Sound IF, detector, and amplifier

D. Video detector and amplifiers

E. Chrominance and color sync sections

F. Sync separators and AGC

G. Vertical and horizontal deflection circuits

H. High voltage circuits

VIII. **Characteristics and functions of the RF tuner**

A. The tuner is the device which selects the channel frequency to be processed by the receiver.

1. VHF channels 2 through 13
2. UHF channels 14 through 69

B. The tuner consists of three stages: the RF amplifier, the oscillator, and the mixer.

1. The RF amplifier amplifies the signals from the receiving antenna.

INFORMATION SHEET

2. The oscillator generates a signal to beat, or heterodyne, against the incoming channel frequency.

3. The mixer stage mixes, or heterodynes, the oscillator frequency against the channel RF frequency to produce an IF frequency that is constant for all channels.

   (NOTE: The video IF is 45.75 MHz; the sound IF is 41.25 MHz.)

IX. Characteristics and functions of the video IF amplifier

A. The IF section amplifies the intermediate frequencies produced by the tuner.

B. Stagger tuning or wideband amplifiers and filters used in the multiple amplification stages.

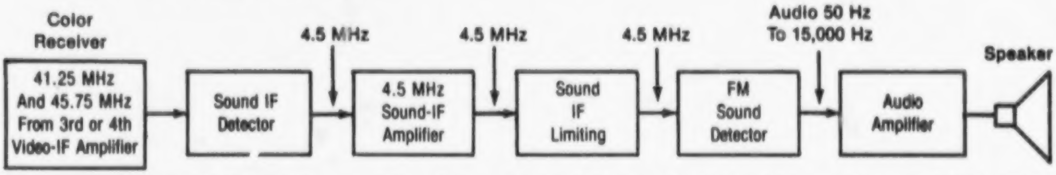
(NOTE: Stagger tuning is the aligning of successive stages to slightly different frequencies to obtain a wider bandpass.)

1. The sound IF is 41.25 MHz.

2. The video IF is 45.75 MHz.

X. Major stages of the sound section and their functions

A. The major stages of the sound section are the sound IF, the FM detector, and the audio amplifier.


Color Receiver
41.25 MHz And 45.75 MHz From 3rd or 4th Video-IF Amplifier
Sound IF Detector
4.5 MHz
4.5 MHz Sound-IF Amplifier
4.5 MHz
Sound IF Limiting
4.5 MHz
FM Sound Detector
Audio 50 Hz To 15,000 Hz
Audio Amplifier
Speaker

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B. The majority of TV receivers separate the sound and video signals at the last video IF stage.

C. Video and sound carriers are first mixed in a detector circuit to produce a 4.5 MHz sound IF.

D. Sound IF stages amplify the sound IF signal to a usable level.

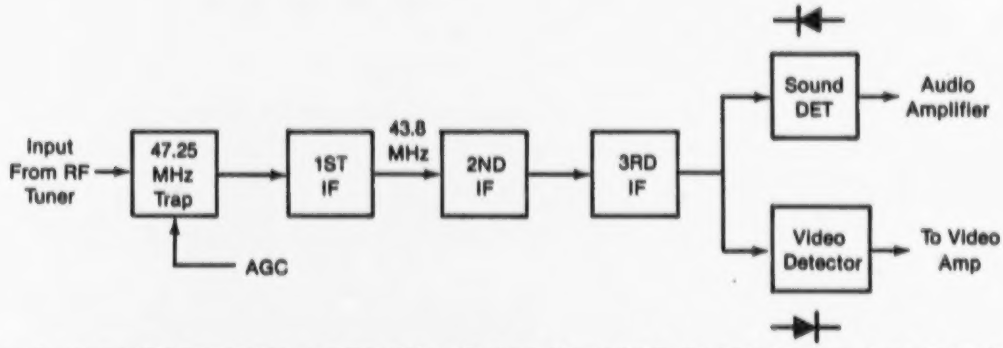
E. The sound detector demodulates the signal to produce the original audio frequency.

F. The audio amplifier amplifies the signal to a sufficient level to drive the speaker.

INFORMATION SHEET

XI. Characteristics and functions of the video detector and video amplifiers

A. The output of the video IF section is coupled to the video detector stage.



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B. The video IF carrier signal is heterodyned against its sidebands in the video detector resulting in beat frequencies that constituted the original modulating information.

1. Luminance (Y) signal
2. Chrominance, or I and Q signals

C. Four separate functions are accomplished after video detection.

1. Amplification of the brightness portion of the signal
2. Separation of the color sidebands from the signal
3. Color burst signal is applied to the color synchronization circuits to recreate the color subcarrier.
4. The AGC and sync separator signals are incorporated into the signal processing circuits.

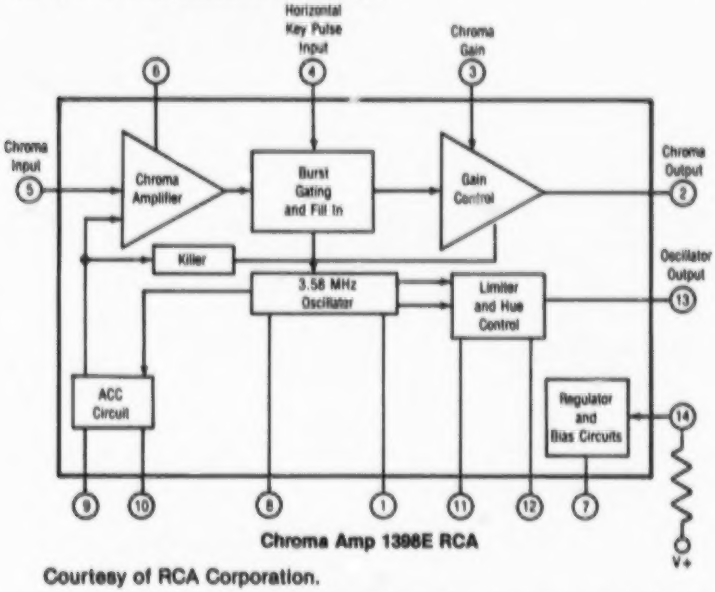
XII. Characteristics and functions of the chrominance section

A. The chrominance section in modern receivers consists of a number of processing circuits that have two primary purposes: that of color signal reinsertion and synchronization, and that of color signal demodulation.

INFORMATION SHEET

B. The color subcarrier reinsertion and sync section includes a bandpass amplifier, the burst gate, a 3.58 MHz oscillator, the color killer, and control circuits.

(NOTE: Modern day television receivers may have all these circuits contained in one integrated circuit chip.)


Horizontal Key Pulse Input
Chroma Gain
6
4
3
Chroma Input
5
Chroma Amplifier
Burst Gating and Fill In
Gain Control
Chroma Output
2
Killer
3.58 MHz Oscillator
Limiter and Hue Control
Oscillator Output
13
ACC Circuit
Regulator and Bias Circuits
14
9
10
8
1
11
12
7
V+

Chroma Amp 1398E RCA

Courtesy of RCA Corporation.

1. The bandpass amplifier amplifies the specific band of frequencies associated with the chroma signal.

2. The burst gate selects and amplifies the color burst signal.

3. The color killer develops a DC voltage to control the operation of the chroma amplifier.

   (NOTE: The color killer acts as a switch to turn the chroma amplifier on or off depending on whether a color signal is being received. When no color signal is being received, the switch is on which causes an excessive bias on the chroma amplifier which in effect turns it off. When a color signal is received, the color killer allows the chroma amplifier to operate.)

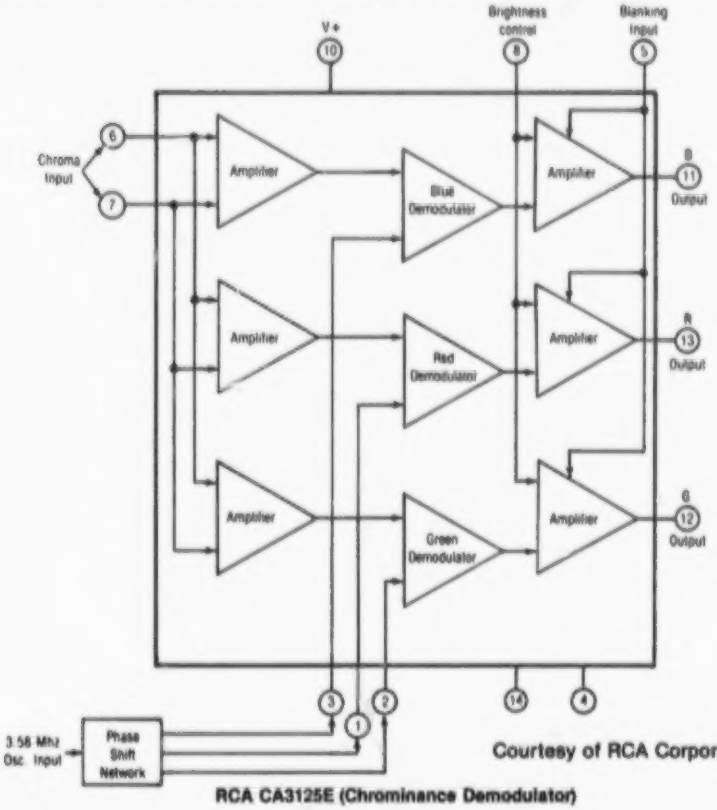
4. Control circuits provide for gain and hue adjustments as well as the automatic color control and tint control circuitry.

5. The 3.58 MHz color oscillator generates and reinserts the 3.58 MHz color subcarrier signal using the color burst signal to synchronize the phase and frequency of the 3.58 MHz oscillator to that of the original at the transmitter site.

INFORMATION SHEET

C. Demodulation may be accomplished with any one of a number of demodulation systems and then amplified for transfer to picture tube.

(NOTE: This is typically accomplished with a single IC in modern receivers.)


V+
10
Brightness control
8
Blanking input
5
Chroma input
6
7
Amplifier
Amplifier
Amplifier
Blue Demodulator
Red Demodulator
Green Demodulator
Amplifier
Amplifier
Amplifier
B
11
Output
R
13
Output
G
12
Output
3
1
2
14
4
3.58 Mhz Osc. Input
Phase Shift Network

Courtesy of RCA Corporation.

RCA CA3125E (Chrominance Demodulator)

D. Convergence circuits are necessary to position the electron beams in the picture tube for proper alignment with the red, green, and blue phosphor dots in the picture tube.

XIII. **Characteristics of the AGC and synchronization circuits**

A. The automatic gain control (AGC) circuit develops a DC voltage that affects the gain of both picture and sound amplifiers in the RF and IF sections of the receiver to counteract variances in signal strength.

B. The sync pulse separator removes the sync pulses from the detected video signal and amplifies them.

INFORMATION SHEET

C. The sync pulses are applied to the vertical and horizontal deflection circuits through integrating and differentiating networks.

1. The integrator is a low-pass filter which feeds the vertical oscillator circuit to produce pulses of longer duration.

2. The differentiator is a high-pass filter circuit used to produce pulses of shorter duration for the horizontal oscillator circuit.

XIV. **Characteristics and functions of the deflection circuits** (Transparency 3)

A. Horizontal and vertical deflection circuits provide synchronized waveforms used for the deflection of the electron beam in the scanning of the screen for reproduction of the picture.

B. The horizontal and vertical deflection circuits receive synchronizing pulses from the sync separator section.

1. The vertical deflection circuits produce a sawtooth waveform that is applied to the vertical deflection coils on the CRT.

2. The horizontal deflection circuits produce a sawtooth waveform that is applied to the horizontal deflection coils on the CRT.

3. An assembly made up of horizontal and vertical deflection coils is known as a yoke.

C. The magnetic fields produced by the energized deflection coils cause the electron beam to scan the picture tube.

D. The high voltage circuits use the output pulses of the horizontal deflection circuit that are produced during retrace to produce the high voltage (after rectification) required for focus and CRT anodes of the picture tube.

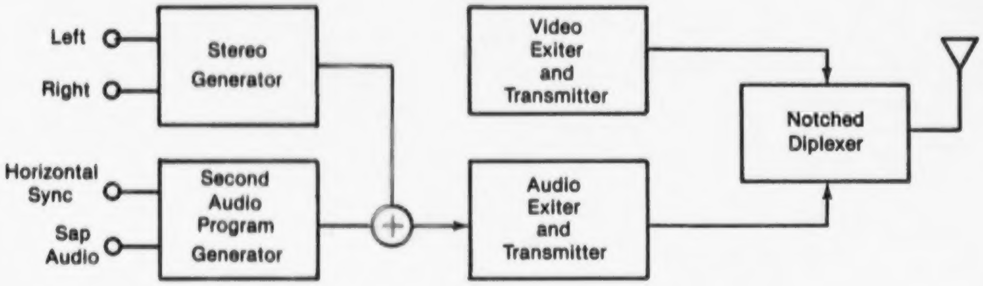
XV. **Standards for stereo sound in television broadcast**

A. In 1984, the FCC adopted guidelines proposed by the Broadcast Television Systems Committee (BTSC) of the Electronics Industries Association providing for multiple audio channels within the television band.

(NOTE: These are guidelines as opposed to standards. The guidelines specify limits on a range of possibilities, yet leave room for the additional audio capabilities when new technology becomes available.)

INFORMATION SHEET

B. The BTSC transmission system was developed by Zenith Electronics and allows the signals to be compressed into a narrow band at the transmitter and expands the audio spectrum at the receiver to recover the multiple channel signals.


Left
Right
Stereo Generator
Horizontal Sync
Sap Audio
Second Audio Program Generator
Video Exiter and Transmitter
Audio Exiter and Transmitter
Notched Diplexer

C. A main audio channel provides sound for conventional monaural receivers and a combination of L + R stereo channel signal for receivers equipped with decoding circuitry.

D. A stereo subchannel provides the L – R stereo difference signal.

E. A pilot tone channel provides a reference frequency for decoding the stereo signals.

F. A stereo subchannel which may be used as a second audio program channel allows a narration of a program simultaneously in a second language.

G. Professional channels allow for television station communications and control functions.

XVI. **General safety precautions for television service or repair**

A. Always wear eye protection when working around picture tubes or when soldering.

B. Use an isolation transformer to reduce the danger of electrical shock and damage to equipment.

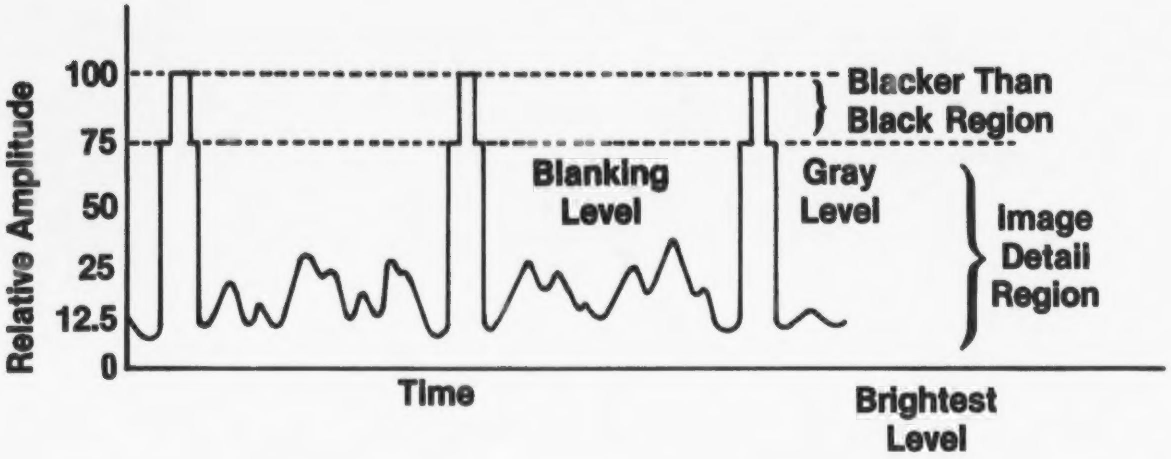
C. Know the location of the high-voltage points and avoid contact with them.

D. Place one hand in your pocket when working around dangerous voltages and currents so that you may prevent the completion of a potentially lethal circuit through your chest from one hand to the other.

E. Use only a high voltage probe to measure the CRT anode voltage; follow manufacturer's instructions for proper use.

F. Properly discharge CRT and power supply before performing resistance measurements, replacing components, or handling chassis or circuit components.

Composite Video Envelope



(NOTE: Signal may be inverted when viewed on an oscilloscope.)

Video Systems: TV Principles and Servicing. 2nd ed. Kamarin S. Badrkhan. Copyright © 1986.
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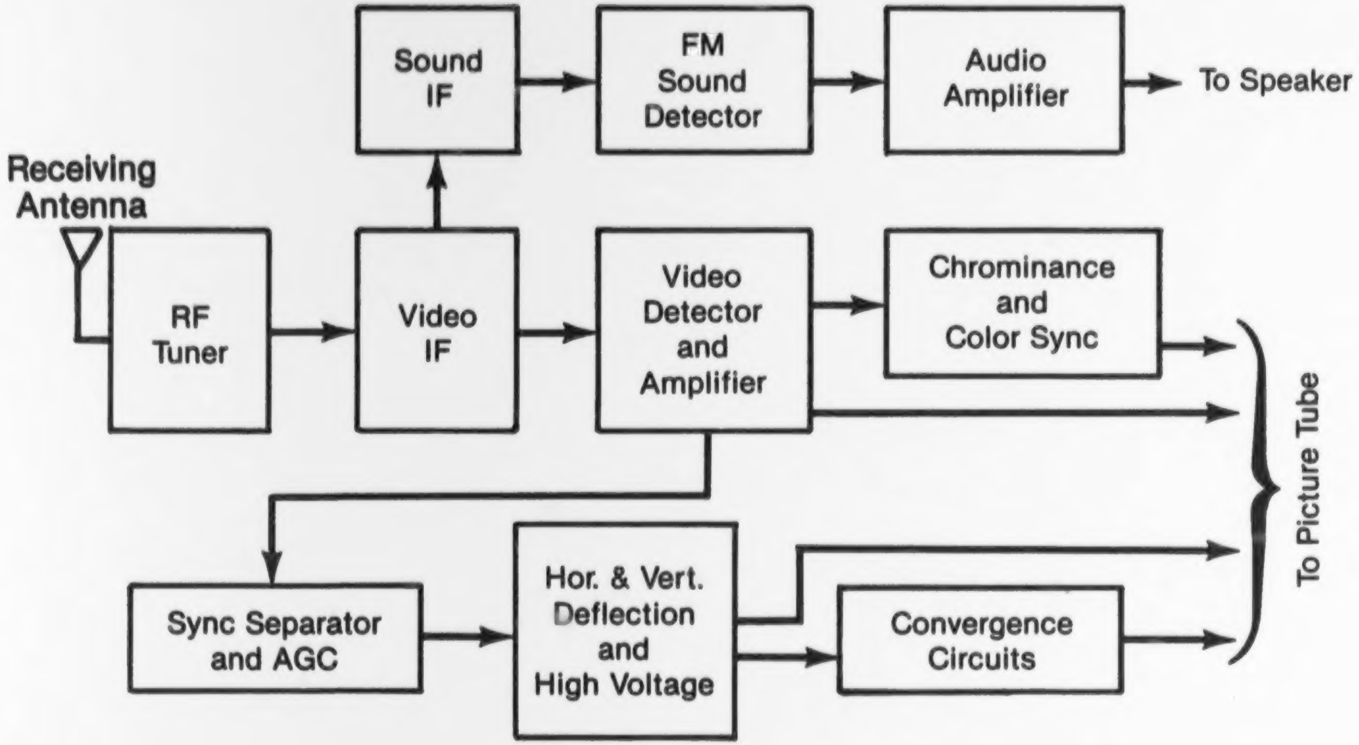
Simplified Block Diagram



Receiving Antenna

RF Tuner

Video IF

Sound IF

FM Sound Detector

Audio Amplifier

To Speaker

Video Detector and Amplifier

Chrominance and Color Sync

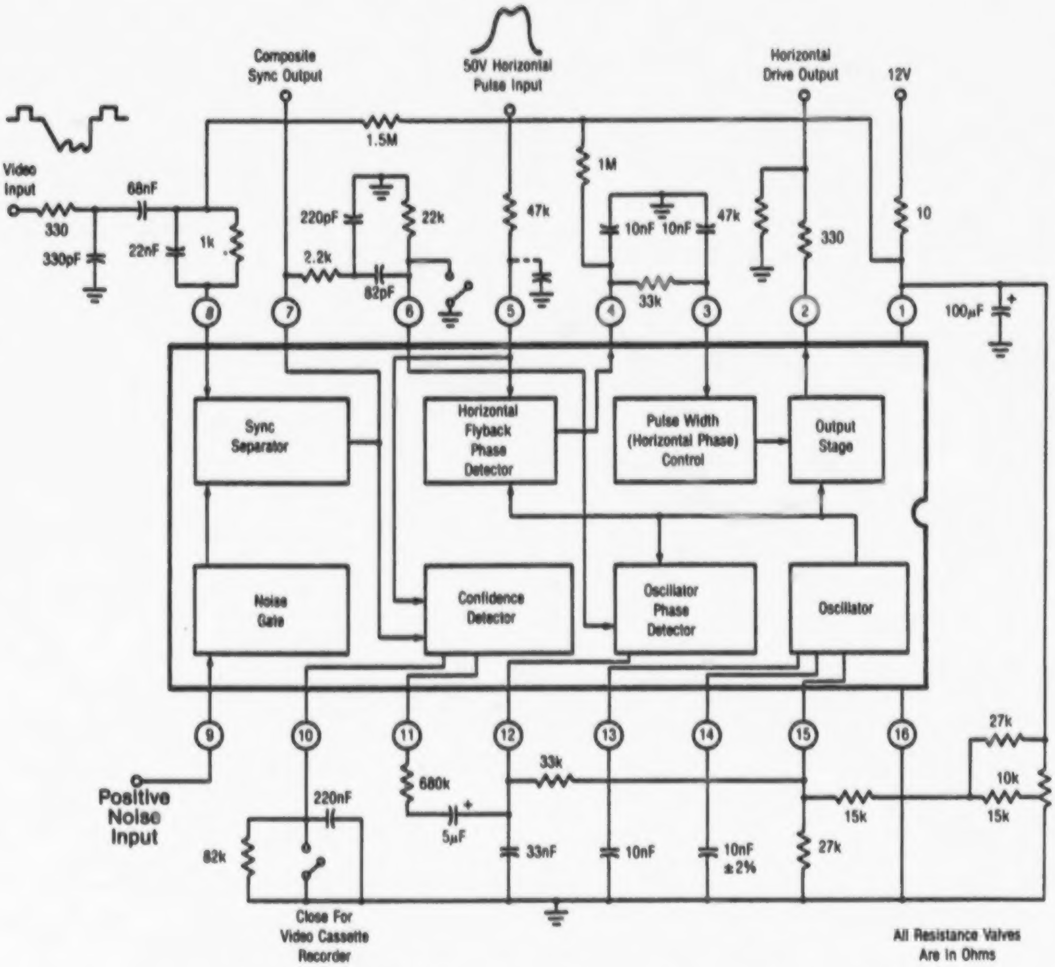
Sync Separator and AGC

Hor. & Vert. Deflection and High Voltage

Convergence Circuits

To Picture Tube

Horizontal Deflection System


Composite Sync Output
50V Horizontal Pulse Input
Horizontal Drive Output
12V
Video Input
330
330pF
68nF
22nF
1k
1.5M
220pF
22k
2.2k
82pF
47k
1M
10nF
10nF
47k
33k
330
10
100µF
Sync Separator
Horizontal Flyback Phase Detector
Pulse Width (Horizontal Phase) Control
Output Stage
Noise Gate
Confidence Detector
Oscillator Phase Detector
Oscillator
Positive Noise Input
220nF
82k
680k
5µF
33k
33nF
10nF
10nF ±2%
27k
15k
27k
10k
15k
Close For Video Cassette Recorder
All Resistance Valves Are In Ohms

RCA CA920AE (Horizontal Oscillator IC)

Reprinted with permission from RCA Corporation.

INTRODUCTON TO VIDEO
UNIT IX

JOB SHEET #1 — VIEW VIDEO WAVEFORMS

A. Equipment and materials needed

1. Television receiver
2. TV receiver schematic
3. TV receiver component layout diagram
4. Oscilloscope and probe
5. Isolation transformer
6. Color bar generator

B. Procedure

1. Connect the TV to the isolation transformer.
2. Turn the set on and tune to viewable channel.
3. Locate the video detector test point in the TV receiver.
4. Attach the oscilloscope to the test point and adjust for a viewable composite video waveform.

   (NOTE: When you have a composite video waveform displayed on the oscilloscope, have your instructor view waveform and initial if correct.)

   Instructor initial ____________

5. Locate the test point on your receiver schematic where the burst signal may be found.
6. Attach your oscilloscope to the test point and adjust for a stable presentation on the oscilloscope.

   (NOTE: When you have a color burst waveform displayed on the oscilloscope, have your instructor view waveform and initial if correct.)

   Instructor initial ____________

7. Attach the color bar generator to the VHF input of the television receiver.

JOB SHEET #1

8. Adjust the television for stable color bars on the picture tube screen.

9. Locate the test points for a color output to the picture tube on your schematic.

10. Attach your oscilloscope to the test point and adjust for a stable waveform display.

11. Set oscilloscope time base for horizontal rate.

    (NOTE: When you have a color bar pattern waveform displayed on the oscilloscope, have your instructor view waveform and initial if correct.)

    Instructor Initial ____________

12. Turn off all power to TV and test instruments.

13. Return test equipment and materials to their proper storage location.

INTRODUCTION TO VIDEO
UNIT IX

JOB SHEET #1 PRACTICAL TEST — VIEW VIDEO WAVEFORMS

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask you instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:		YES	NO
1.	Checked out proper tools and materials.	______	______
2.	Connected TV to isolation transformer.	______	______
3.	Turned set on to viewable channel.	______	______
4.	Located the video detector test point in the TV receiver.	______	______
5.	Attached oscilloscope to test point and adjusted for a viewable composite video waveform.	______	______
6.	Located test point on receiver schematic where burst signal may be found.	______	______
7.	Attached oscilloscope to test point and adjusted for a stable presentation of the oscilloscope.	______	______
8.	Attached color bar generator to the VHF input of the television receiver.	______	______
9.	Adjusted television for stable color bars on the picture tube screen.	______	______
10.	Located test points for a color output to the picture tube on schematic.	______	______
11.	Attached oscilloscope to test point and adjusted for stable waveform display.	______	______
12.	Turned off all power to TV and test instruments.	______	______
13.	Checked in/put away equipment and materials.	______	______
14.	Cleaned the work area.	______	______
15.	Used proper equipment correctly.	______	______
16.	Performed steps in a timely manner (__hrs. __min. __sec.)	______	______
17.	Practiced safety rules throughout procedure.	______	______
18.	Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Waveform	Clear, concise			Fuzzy
	4	3	2	1
Oscilloscope setting	Proper sweep rate			Improper sweep rate
	4	3	2	1
Test point	Correctly located			Incorrectly located

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

INTRODUCTION TO VIDEO
UNIT IX

NAME ____________________________ SCORE ______________________

TEST

1. Match the terms on the right with their correct definitions.

_____a. Sound or audio

_____b. Picture portion of a television signal; signal that carries visual information

_____c. Coupling unit that provides for more than one transmitter to broadcast from the same antenna

_____d. Small amount that remains of a complete original sideband

_____e. The fineness or detail within an image

_____f. A single light or dark element within a picture

_____g. A whole that is a combination of two or more parts

_____h. The brightness information within a composite video signal

_____i. The color information within the composite video signal

_____j. To combine or superimpose frequencies to obtain a different frequency

_____k. Frequencies on either side of carrier signal that are produced through modulation

_____l. A waveform of short duration that contains phase and frequency reference information for color television circuits

1. Aural
2. Chrominance signal
3. Color burst
4. Composite video
5. Diplexer
6. Heterodyne
7. Luminance signal
8. Picture element
9. Resolution
10. Sideband
11. Vestigial-sideband
12. Video

2. Name three applications of television systems.

a. ____

b. ____

c. ____

TEST

3. Complete the following chart concerning selected standards of transmitted video signals by inserting the word(s) or number(s) that best complete the chart.

NTSC System Standards

a. Number of lines per frame __________
b. Number of frames per second __________
c. Field frequency __________ Hz
d. Channel width __________ MHz
e. Color subcarrier __________ MHz

4. Complete the following statements concerning elements of the television picture by inserting the word(s) that best complete(s) each statement.

a. Detail, resolution, and definition are terms which refer to __________ or __________ of the picture.

b. __________ is the difference in the brightness and darkness between adjacent colors or between adjacent shades of black, white, or gray.

c. Color hue or tint refers to the dominant __________ .

d. Color saturation is the amount of __________ in an image.

5. Name the four components within the composite color video signal.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

6. Complete the following statements concerning characteristics of the color burst and synchronizing pulses by inserting the word(s) that best completes each statement.

a. The color burst is generated at the studio and provides a __________ and __________ reference and is propagated through the entire transmission network.

b. The color burst signal serves as reference for a __________ MHz oscillator in the receiver.

c. The color burst signal contains __________ to __________ cycles of subcarrier frequency.

TEST

d. The color burst signal is located on the "____________ ____________" of the horizontal blanking pulse.

e. The ____________ Hz horizontal sync pulse has a duration of about 5.4 μs with the leading edges separated by 63.5 μs.

f. The 15,750 Hz ____________ blanking pulses have a duration of about 10 μs each.

g. The 60 Hz ____________ blanking pulses have a duration of 830 to 1330 μs.

7. List major stages in a color television receiver.

a. ____

b. ____

c. ____

d. ____

e. ____

f. ____

8. Match the stages in the RF tuner on the right with their correct functions.

_____a.	Generates a signal to beat, or heterodyne, against the incoming channel frequency	1. RF amplifier
_____b.	Amplifies the signals from the receiving antenna	2. Oscillator
_____c.	Mixes, or heterodynes, the oscillator frequency against the channel RF frequency to produce an IF frequency that is constant for all channels	3. Mixer

9. Complete the following statements concerning the characteristics and functions of the video IF amplifier by inserting the word(s) that best complete(s) each statement.

a. The IF section amplifies the intermediate frequencies produced by the ____________.

b. ____________ tuning or wideband amplifiers and filters are used in the multiple amplification stages.

c. The intercarrier ____________ IF frequency is 41.25 MHz.

d. The ____________ IF is 45.75 MHz.

TEST

10. Name the three major stages of the sound section and give their functions.

    a. __________ Function: ______________________________

    ____

    ____

    b. __________ Function: ______________________________

    ____

    ____

    c. __________ Function: ______________________________

    ____

    ____

11. Complete the following statements concerning the characteristics and functions of the video detector and video amplifiers by inserting the word(s) that best complete(s) each statement.

    a. The output of the video IF section is coupled to the video __________ stage.

    b. The video carrier signal (IF) is __________ against its sidebands in the video detector resulting in beat frequencies that constituted the original modulating information.

        1) __________ (Y) signal

        2) __________ , or I and Q signals

    c. After the video detector accomplishes the separation of the color sidebands from the complete signal, the

        1) Color __________ is applied to the color synchronization circuits to recreate the color subcarrier.

        2) The AGC and __________ separator signals are incorporated into the signal processing circuits.

TEST

12. Match terms related to the characteristics and functions of the chrominance section with their correct descriptions.

_____a. Amplifies the specific band of frequencies associated with the chroma signal

_____b. Selects and amplifies the color burst signal

_____c. Develops a DC control voltage to control the operation of the chroma amplifier

_____d. Provides for gain and hue adjustments as well as the automatic color control and tint control circuitry

_____e. Generates and reinserts the 3.58 MHz color subcarrier signal using the color burst signal to synchronize the phase and frequency of the 3.58 MHz oscillator to that of the original at the transmitter site

1. Control circuits
2. Burst gate
3. Bandpass amplifier
4. Color killer
5. Color oscillator

13. Complete the following statements concerning characteristics of the AGC and synchronization circuits by inserting the word(s) that best complete(s) each statement.

a. The automatic gain control (AGC) circuit develops a ____________ voltage that affects the gain of both picture and sound amplifiers in the RF and IF sections of the receiver to counteract variances in signal strength.

b. The sync pulse separator removes the sync pulses from the ____________ video signal and amplifies them.

c. The sync pulses are applied to the vertical and horizontal deflection circuits through ____________ and ____________ networks.

14. Complete the following statements concerning the characteristics and functions of the deflection circuits by inserting the word(s) that best complete(s) each statement.

a. Horizontal and vertical deflection circuits provide synchronized waveforms used for the deflection of the ____________ ____________ in the scanning of the screen for reproduction of the picture.

b. The horizontal and vertical deflection circuits receive synchronizing pulses from the ____________ ____________ section.

c. The magnetic fields produced by the energized deflection coils cause the electron beam to ____________ the picture tube.

TEST

15. Select true statements concerning standards for stereo sound in television broadcast by placing an "X" in the blanks preceding the true statements.

_____a. In 1984, the FCC adopted guidelines proposed by the BTSC of the EIA providing for multiple audio channels within the television band.

_____b. A main audio channel provides the L-R stereo difference signal.

_____c. A pilot tone channel provides a reference frequency for decoding the stereo signals.

_____d. Professional channels allow for television station communications and control functions.

16. Complete the following statements concerning general safety precautions for television service or repair by inserting the word(s) that best complete(s) each statement.

a. Always wear eye protection when working around ____________ ____________ or when ____________.

b. Use an ____________ transformer to reduce the danger of electrical shock and damage to equipment.

c. Know the location of the ____________-____________ points and avoid contact with them.

d. Place one hand in your ____________ when working around dangerous voltages and currents so that you may prevent the completion of a potentially lethal circuit through your ____________ from one hand to the other.

e. Use only a high voltage ____________ to measure the CRT anode voltage; follow manufacturer's instructions for proper use.

f. Properly discharge CRT and ____________ ____________ before performing resistance measurements, replacing components, or handling chassis or circuit components.

(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

17. Demonstrate the ability to view video waveforms. (Job Sheet #1)

INTRODUCTION TO VIDEO
UNIT IX

ANSWERS TO TEST

1. a. 1
   b. 12
   c. 5
   d. 11
   e. 9
   f. 8
   g. 4
   h. 7
   i. 2
   j. 6
   k. 10
   l. 3

2. Any three of the following:

   a. Commercial broadcast
   b. Subscription television
   c. Master antenna television system (MATV)
   d. Closed circuit television system (CCTV)
   e. Cable television
   f. Computer terminal/display system

3. a. 525
   b. 30
   c. 60
   d. 6
   e. 3.58

4. a. Sharpness, clarity
   b. Contrast
   c. Color
   d. Color

5. (NOTE: Answers may be in any order.)

   a. Luminance
   b. Chrominance
   c. Color burst
   d. Synchronizing pulses

6. a. Frequency, phase
   b. 3.58
   c. Eight, eleven
   d. Back porch
   e. 15,750
   f. Horizontal
   g. Vertical

ANSWERS TO TEST

7. Any six of the following:

   a. RF tuner
   b. Video IF amplifier
   c. Sound IF, detector, and amplifier
   d. Video detector and amplifiers
   e. Chrominance and color sync sections
   f. Sync separators and AGC
   g. Vertical and horizontal deflection circuits
   h. High voltage circuits

8. a. 2
   b. 1
   c. 3

9. a. Tuner
   b. Stagger
   c. Sound
   d. Video

10.

a.	Sound IF	Function: Amplifies the intermediate sound frequency
b.	Detector	Function: Demodulates the signal to produce the original audio
c.	Audio amp	Function: Amplifies the audio signal to a level sufficient to drive the speaker

11. a. Detector
    b. Heterodyned
       1) Luminance
       2) Chrominance
    c. 1) Burst
       2) Sync

12. a. 3
    b. 2
    c. 4
    d. 1
    e. 5

ANSWERS TO TEST

13. a. DC
    b. Detected
    c. Integrating, differentiating

14. a. Electron beam
    b. Sync separator
    c. Scan

15. a, c, d

16. a. Picture tubes, soldering
    b. Isolation
    c. High-voltage
    d. Pocket, chest
    e. Probe
    f. Power supply

17. Performance skills evaluated to the satisfaction of the instructor

TRANSMISSION LINES
UNIT X

UNIT OBJECTIVE

After completion of this unit, the student should be able to distinguish between types of transmission lines and measure standing wave ratio on a transmission line. Competencies will be demonstrated by completing the unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to transmission lines with their correct definitions.
2. State the purpose of a transmission line.
3. Match types of losses in transmission lines with their correct descriptions.
4. Match types of transmission lines with their correct definitions.
5. Complete statements concerning characteristics of transmission lines.
6. Complete statements concerning the characteristics of resonant and nonresonant lines.
7. Identify types of transmission line terminations.
8. Write a formula for determining standing wave ratio.
9. Describe how to measure standing wave ratio on a transmission line using an SWR meter.
10. Complete statements concerning matching impedances of a transmission line to that of a load.

TRANSMISSION LINES
UNIT X

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Integrate the following activities throughout the teaching of this unit:

   1. Show films or videotapes related to transmission lines.
   2. Show different types of transmission lines.
   3. Illustrate transmission line specifications by using supply catalogs and specification sheets.
   4. Demonstrate how to measure standing wave ratio.
   5. Demonstrate the tuning of a matching stub.
   6. Visit installations in industry where special transmission lines are installed.
   7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

H. Give test.

I. Evaluate test.

J. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Electronic Communications*. Benton Harbor, MI: Heath Company, 1981.

B. Hardy, James K. *Electronic Communications Technology*. Englewood Cliffs, NJ: Prentice-Hall, 1986.

C. Kennedy, George. *Electronic Communication Systems*. Third Edition. New York: McGraw-Hill Book Company, 1985.

D. Schrader, Robert L. *Electronic Communication*. Fifth Edition. New York: McGraw-Hill Book Company, 1985.

E. Miller, Gary M. *Modern Electronic Communication*. Third Edition. Englewood Cliffs, NJ: Prentice-Hall, 1983.

F. Gerrish, Howard H. and William E. Dugger. *Electricity and Electronics*. South Holland, IL: Goodheart-Willcox Company, Inc., 1980.

TRANSMISSION LINES
UNIT X

INFORMATION SHEET

I. **Terms and definitions**

A. Balanced line — A transmission line in which both wires of the line carry RF current and the current in each wire is 180 degrees out of phase with the other

B. Matching stub — Device placed on a transmission line which varies the impedance of the line to provide for line-to-load impedance match

C. Reflected wave — A wave that is returned along a transmission line from a load back towards the source when an impedance mismatch exists between line and load

D. Skin effect — Tendency of currents at high frequencies to flow near the surface of a conductor

E. Standing wave — Distribution of current and voltage amplitudes along a transmission line as a result of the deflection of energy from a point where a mismatch of impedance occurs

F. Standing wave ratio — Ratio of current or voltage at a maximum value point on a transmission line to a minimum value voltage or current point on the line

G. Transmission line — Material structure forming a continuous path from one place to another and used for directing the transmission of electromagnetic energy along this path; a conductor or series of conductors used to carry energy from a source to a load

H. Unbalanced line — A transmission line in which one wire is at ground potential, while the other wire carries the RF current

II. **Purpose of a transmission line** — In communication electronics it is to transfer maximum energy with minimum loss

III. **Losses in transmission lines**

(NOTE: Losses in transmission lines are due to resistive, inductive, and capacitive properties of the line.)

A. Copper loss (I^2R loss) — A resistive power loss due to resistance in the conductor

B. Loss due to skin effect — Energy losses, dissipated in the form of heat, that occur at high frequencies

INFORMATION SHEET

C. Radiation loss — A direct function of frequency and occurs when a small portion of the rapidly changing field around the conductor is lost into space

D. Induction loss — Occurs when the expanding and collapsing magnetic fields induce a voltage and current into conduction surfaces near the transmission line

E. Dielectric loss — Occurs when the insulation between conductors in a two-wire transmission line act as a dielectric

F. Leakage current losses — Occur due to imperfect dielectric material in transmission lines

IV. **Types of transmission lines** (Transparency 1)

A. The **twisted pair** transmission line is constructed of two insulated conductors twisted together to form a flexible line.

1. Simple construction and inexpensive
2. Used for low-voltage, low frequency applications such as telephone and audio circuits
3. Close spacing of conductors minimizes radiation loss
4. Twisting of conductors minimizes induction loss

B. The **twin lead** transmission consists of two conductors molded into the edges of a polyethelene plastic ribbon.

1. Commonly used as a lead-in from antenna to television receiver
2. Not suitable for high power transmission
3. Major loss is dielectric loss
4. Used for frequencies up to approximately 200 MHz

C. The **open two-wire** transmission line consists of two conductors which are kept the same distance from each other by means of spacers.

1. Distance between the two conductors is approximately one-tenth wavelength or less

   (NOTE: The actual distance between the conductors will depend upon frequency, characteristic impedance required, and the diameter of the conductors.)

INFORMATION SHEET

2. Used for frequencies up to approximately 200 MHz

3. Major power loss is the result of radiation

D. The **flexible coaxial cable** transmission line consists of an inner conductor of solid or stranded wire, separated by an insulating material from an outer concentric conductor of braided wires or metallic foil.

1. Used for high power and high frequency applications

2. Major losses are due to dielectric and skin effect

E. **Rigid coaxial cable** transmission line consists of a center conductor placed inside of a rigid metal tube that functions as the outer shield.

1. Used primarily for high power at frequencies up to 3 GHz

2. Major power losses are due to copper loss

V. **Characteristics of transmission lines**

A. Transmission lines characteristically exhibit some value of capacitance and inductance.

B. Capacitance and inductance of a transmission line is determined primarily by the size of the conductors, the space between the conductors, and the dielectric material.

C. Characteristic impedance (Zo) of a transmission line is determined by the series inductance and shunt capacitance of the line and does not change with line length.

1. Characteristic impedance will change with the cross-sectional area of the conductors.

2. Characteristic impedance will change with the spacing between the conductors.

3. Characteristic impedance (Zo) may be calculated with the formula:

$$Zo = \sqrt{L/C}$$

D. Cutoff frequency is the highest frequency that will pass down a transmission line.

(NOTE: As frequency increases, capacitive reactance between conductors decreases to a point where a major portion of the signal is shunted across the line permitting very little signal to pass along the line.)

INFORMATION SHEET

E. Velocity factor (K) of a transmission line is the comparison of speed that energy flows along a line to the speed of light expressed in formula form as:

$$K = \frac{\text{Speed of energy through line}}{\text{Speed of light}}$$

1. The type of transmission line with the highest velocity factor is the open two-wire line

2. The type of transmission line with the slowest speed is through a twisted pair line with rubber insulation

VI. **Characteristics of resonant and nonresonant lines**

A. A nonresonant transmission line is a transmission line having no reflected waves and no standing waves.

1. A transmission line that is terminated in a load of the same resistive value as its characteristic impedance is a nonresonant line.

2. All of the energy traveling down the line is absorbed by the load resistance.

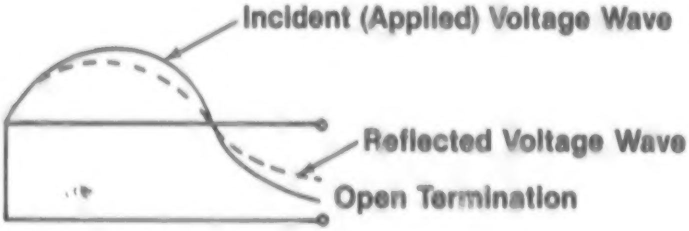
B. A resonant transmission line has a mismatch of impedance between the transmission line and the load.

1. Part of the energy is reflected back to the source.

2. Standing waves are created on the transmission line.

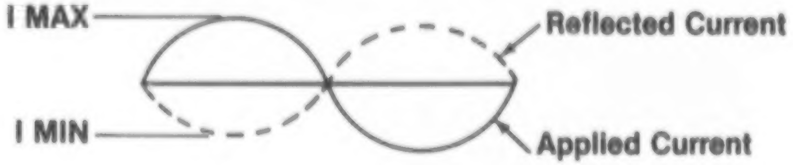
VII. **Types of transmission line terminations** (Transparency 2)

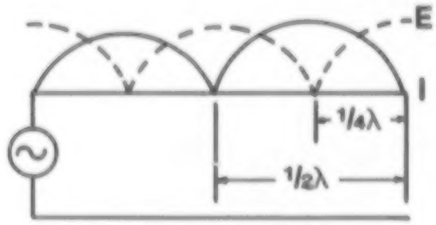
A. A transmission line with an open termination has all the energy reflected back to the source.



INFORMATION SHEET

1. Standing waves appear on the transmission line.


I MAX
I MIN
Reflected Current
Applied Current

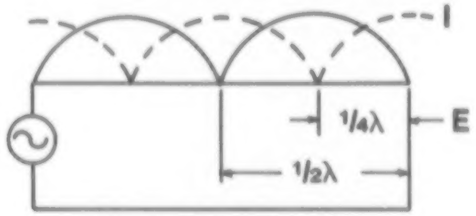


Open Termination

2. Voltage is maximum at the open termination.

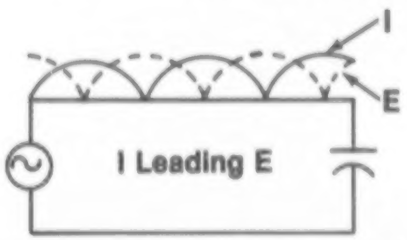
3. Current is minimum at the open termination.

B. A transmission line with a shorted termination has minimum voltage and maximum current across the shorted termination.



Shorted Termination

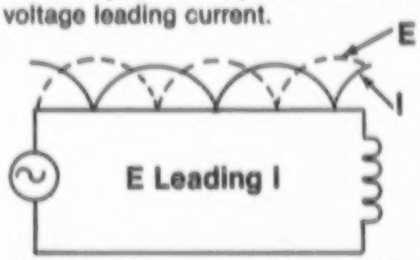
C. Capacitive termination on a transmission line produces a phase difference between reflected current and voltage with current leading voltage.


I
E
I Leading E

Capacitive Reactance Termination

INFORMATION SHEET

D. Inductive termination produces a phase difference in reflected voltage and current with voltage leading current.



Inductive Reactance Termination

E. Resistive termination equal to the impedance of the line absorbs all the energy fed down the line and no reflected waves exist.

1. Resistive termination that greatly exceeds the impedance of the transmission line produces standing waves similar to that of an open termination.

2. Resistive termination of a value considerably smaller than the impedance of the transmission line produces standing wave similar to that of a shorted termination.

VIII. **Determining standing wave ratio**

A. A mismatch between impedance of a transmission line and the load produces standing waves.

1. Standing waves represent a loss of power.

2. Standing waves are undesirable on a transmission line.

B. Standing waves are measured by determining the maximum and minimum voltage or current present.

C. Voltage standing wave ratio (VSWR) may be determined by comparing the maximum and minimum voltages on the line using the formula:

$$\text{VSWR} = E\text{ max} / E\text{ min}$$

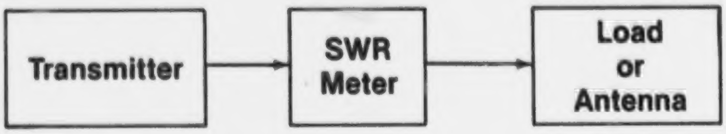
D. Standing wave ratio may also be determined by comparing the characteristic impedance of the line to the resistance of the load using the formula:

$$\text{SWR} = R_L / Zo \text{ or } Zo/R_L \text{ (whichever is larger)}$$

INFORMATION SHEET

IX. **Measuring standing wave ratio** (Transparency 3)

A. Standing-wave ratio is measured by an SWR meter/bridge or reflectometer.


Transmitter
SWR Meter
Load or Antenna

1. SWR meter is connected in series between transmitter and load.
2. SWR meter is calibrated to read SWR directly from the scale.

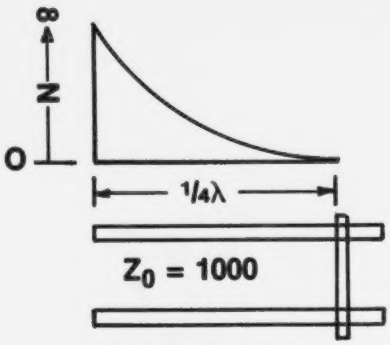
B. A directional wattmeter may be used to measure forward and reflected power on a transmission line.

(NOTE: SWR charts are available for easy conversion of forward and reflected power measurements to standing wave ratios.)

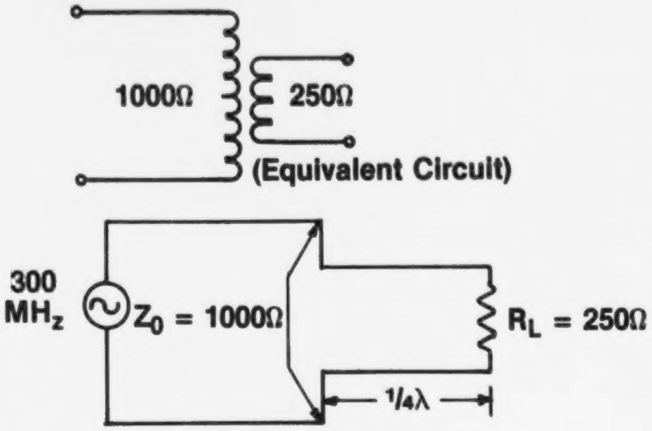
X. **Matching impedances of a transmission line to that of a load**

A. Sections of transmission line can be used to match the characteristic impedance of the line to that of the load.

B. Quarter-wavelength sections of line serve as equivalents to step-up or step-down transformers.


∞
Z
O
¼λ
Z_0 = 1000

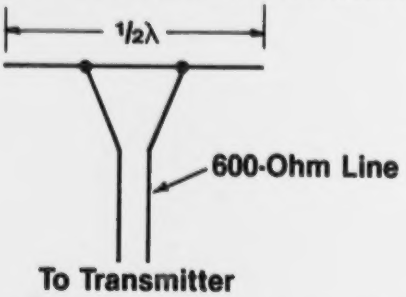
Shorted Line


1000Ω
250Ω
(Equivalent Circuit)
300 MHz
Z_0 = 1000Ω
R_L = 250Ω
¼λ

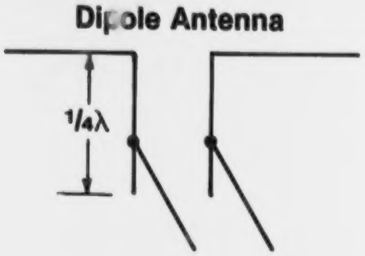
Quarter-Wave Matching

INFORMATION SHEET

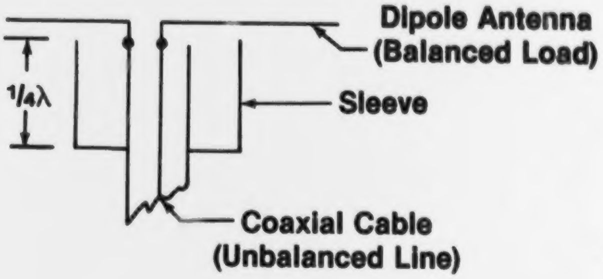
C. A delta match is accomplished by gradually spreading apart the two wires of an open two-wire transmission line until the impedance matches that of the load (antenna)


$1/2\lambda$
600-Ohm Line
To Transmitter

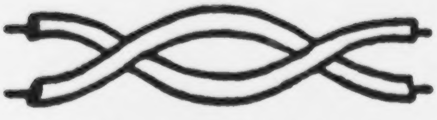
D. A matching stub, made of one-quarter-wavelength transmission line, attached to a dipole antenna may be used to match transmission lines of various impedances to the antenna by connecting the line to the matching impedance point on the stub.


Dipole Antenna
$1/4\lambda$

E. A balun is a device used to match a balanced system to an unbalanced system.

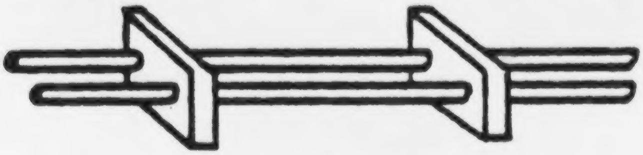

Dipole Antenna
(Balanced Load)
$1/4\lambda$
Sleeve
Coaxial Cable
(Unbalanced Line)

Basic Types of Transmission Lines

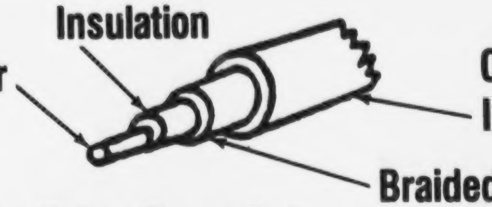


Twisted Pair

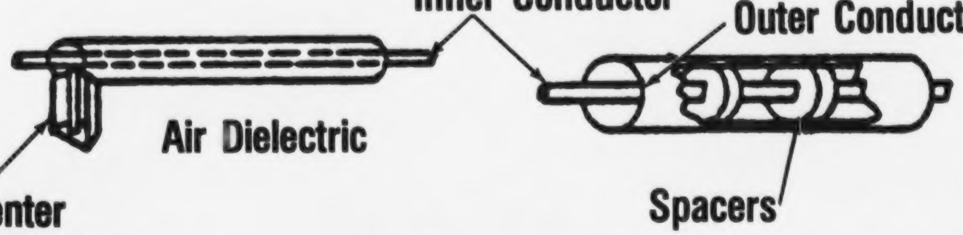
Twin Lead



Open Two Wire

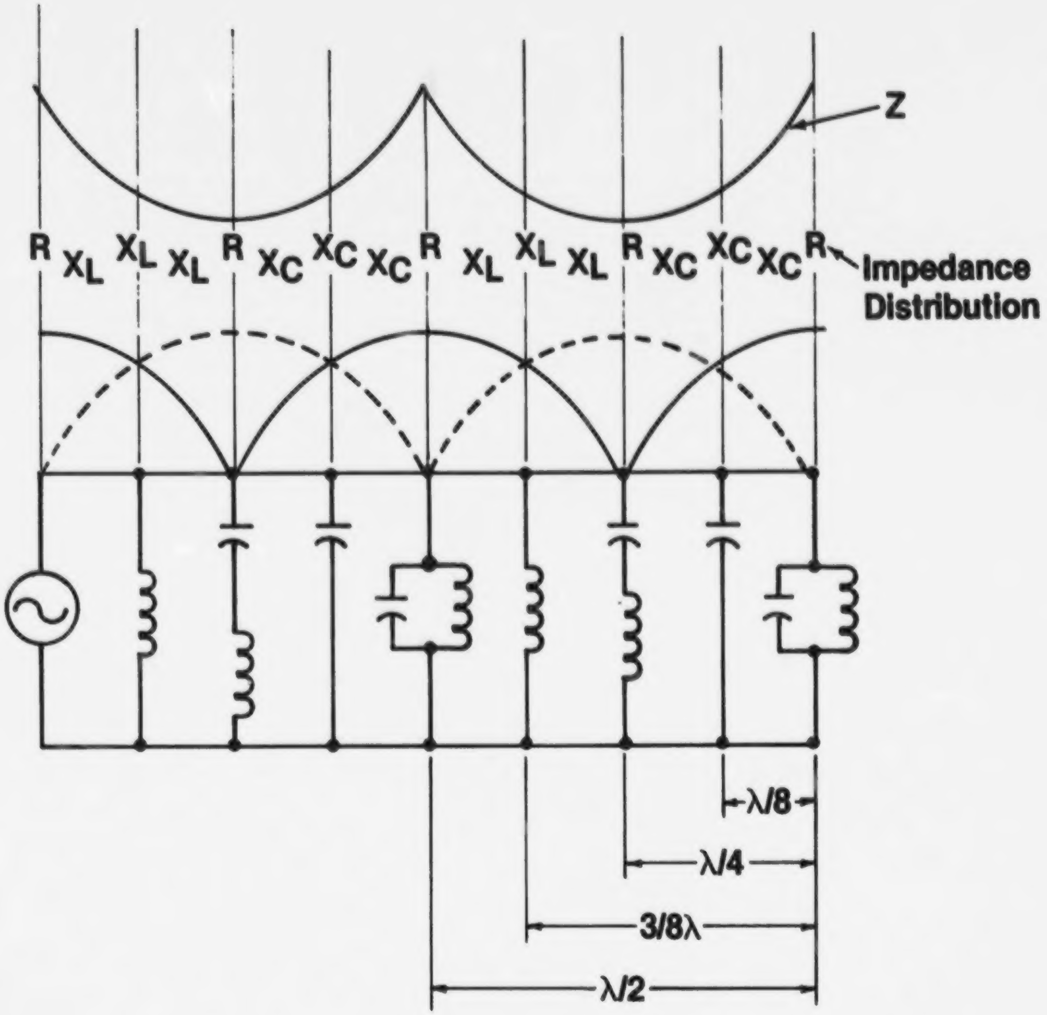

Inner Conductor
Insulation
Outer Insulation
Braided Outer Conductor

Flexible Coaxial

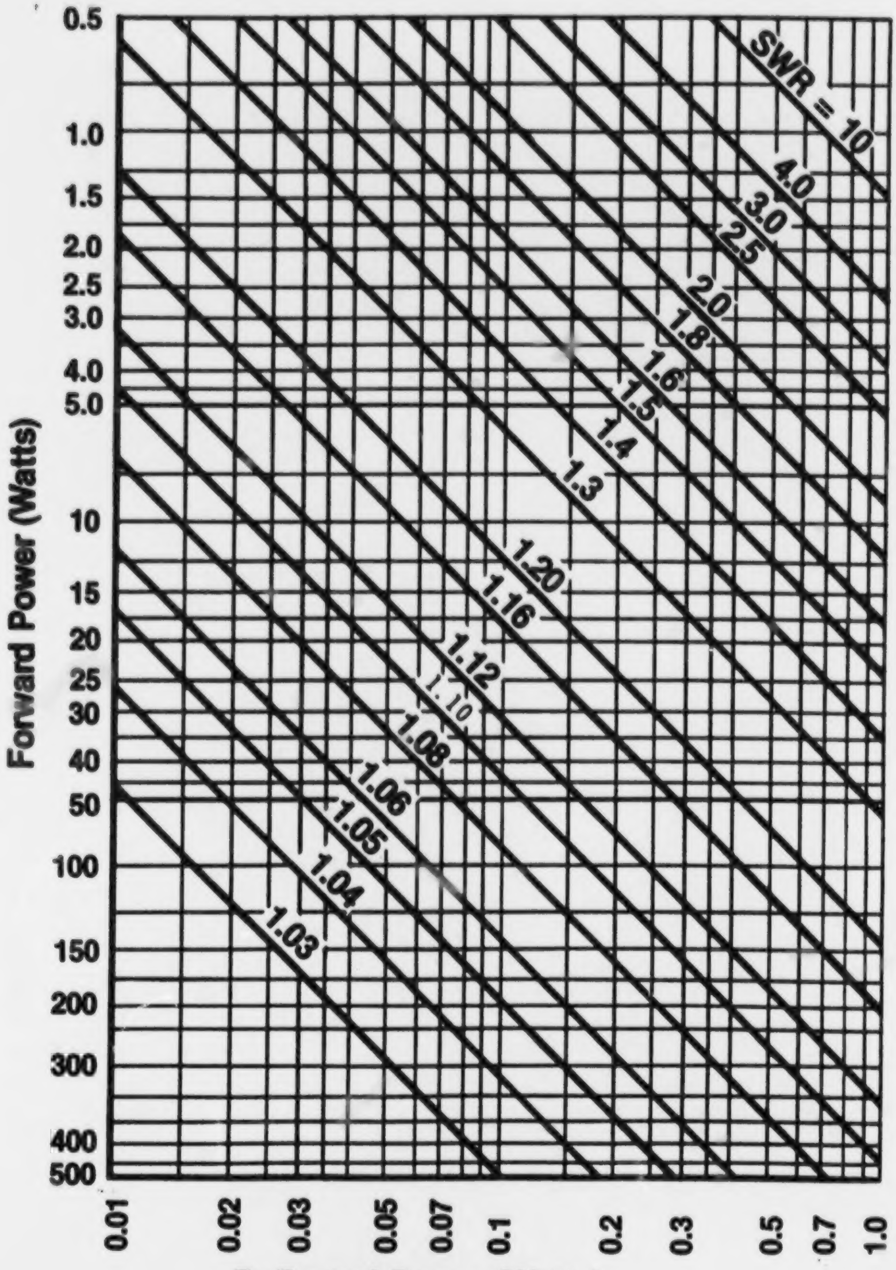

Inner Conductor
Outer Conductor
Air Dielectric
Spacers
Center Conductor Support

Rigid Coaxial

Line Terminations Symbolized by Circuit Terminations With Impedance Distribution


Z
R
X_L
X_L
X_L
R
X_C
X_C
X_C
R
X_L
X_L
X_L
R
X_C
X_C
X_C
R
Impedance Distribution
λ/8
λ/4
3/8λ
λ/2

Standing Wave Ratio Chart



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TRANSMISSION LINES
UNIT X

TEST

NAME ______________________________ SCORE ______________________________

1. Match the terms on the right with their correct definitions.

______a. A wave that is returned along a transmission line from a load back toward the source when an impedance mismatch exists between line and load

______b. Distribution of current and voltage amplitudes along a transmission line as a result of the deflection of energy from a point where a mismatch of impedance occurs

______c. Ratio of current or voltage at a maximum value point on a transmission line to a minimum value voltage or current point on the line

______d. Device placed on a transmission line which varies the impedance of the line to provide for line-to-load impedance match

______e. Tendency of currents at high frequencies to flow near the surface of a conductor

______f. A transmission line in which one wire is at ground potential, while the other wire carries the RF current

______g. A transmission line in which both wires of the line carry RF current and the current in each wire is 180 degrees out of phase with the other

______h. Material structure forming a continuous path from one place to another and used for directing the transmission of electromagnetic energy along this path

1. Balanced line
2. Matching stub
3. Reflected wave
4. Skin effect
5. Standing wave
6. Standing wave ratio
7. Transmission line
8. Unbalanced line

2. State purpose of a transmission line. ____

____

TEST

3. Match the types of losses in transmission lines on the right with their correct descriptions.

_____a. A resistive power loss due to resistance in the conductor

_____b. Energy losses, dissipated in the form of heat, that occur at high frequencies

_____c. A direct function of frequency and occurs when a small portion of the rapidly changing field around the conductor is lost into space

_____d. Occurs when the expanding and collapsing magnetic fields induce a voltage and current into conduction surfaces near the transmission line

_____e. Occurs when the insulation between conductors in a two-wire transmission line act as a dielectric

_____f. Occur due to imperfect dielectric material in transmission lines

1. Copper loss
2. Induction loss
3. Radiation loss
4. Loss due to skin effect
5. Dielectric loss
6. Leakage current losses

4. Match the types of transmission lines on the right with their correct descriptions.

_____a. Transmission line constructed of two insulated conductors twisted together to form a flexible line

_____b. Transmission line consisting of two conductors molded into the edges of a polyethylene plastic ribbon

_____c. Transmission line consisting of two conductors which are kept the same distance from each other by means of spacers

_____d. Transmission line consisting of an inner conductor of solid or stranded wire, separated by an insulating material from an outer concentric conductor of braided wires or metallic foil

_____e. Transmission line consisting of a center conductor placed inside of a rigid metal tube that functions as the outer shield

1. Rigid coaxial cable
2. Flexible coaxial cable
3. Open two-wire
4. Twin lead
5. Twisted pair

TEST

5. Complete the following statements concerning characteristics of transmission lines by inserting the word(s) that best complete(s) each statement.

   a. Transmission lines characteristically exhibit some value of ____________ and ____________.

   b. Capacitance and inductance of a transmission line is determined primarily by the ____________ of the conductors, the ____________ between the conductors, and the ____________ material.

   c. Characteristic impedance of a transmission line is determined by the series ____________ and shunt ____________ of the line and does not change with line length.

   d. ____________ frequency is the highest frequency that will pass down a transmission line.

   e. ____________ factor (K) of a transmission line is the comparison of speed that energy flows along a line to the speed of light.

6. Complete the following statements concerning characteristics of resonant and nonresonant lines by inserting the word(s) that best complete(s) each statement.

   a. A nonresonant transmission line is a transmission line having no ____________ waves and no ____________ waves.

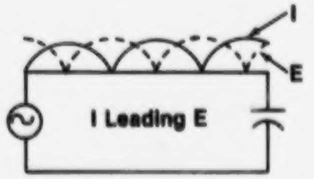
   b. A transmission line that is terminated in a load of the same resistive value as its characteristic impedance is a ____________ line.

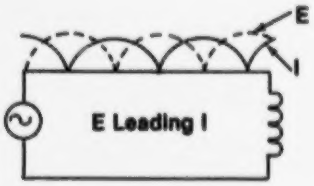
   c. All of the energy traveling down a nonresonant line is ____________ by the load resistance.

   d. A ____________ transmission line has a mismatch of impedance between the transmission line and the load.

   e. ____________ waves are created on a resonant transmission line.

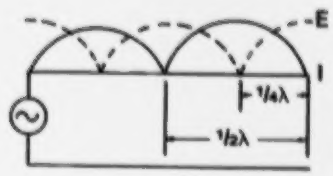
7. Identify types of transmission line terminations shown below.

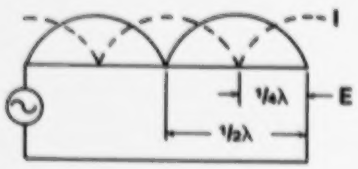




a. ______________________________   b. ______________________________

TEST





c. ______________________________ d. ______________________________

8. Write a formula for determining standing wave ratio.

____

9. Describe how to measure standing wave ratio on a transmission line using an SWR meter. Use diagrams if necessary.

____

____

____

____

____

10. Complete the following statements concerning matching impedances of a transmission line to that of a load by inserting the word that best completes each statement.

a. Sections of ____________ line can be used to match the characteristic impedance of the line to that of the load.

b. ____________-wavelength sections of line serve as equivalents to step-up or step-down transformers.

c. A ____________ match is accomplished by gradually spreading apart the two wires of an open two-wire transmission line until the impedance matches that of the load (antenna).

d. A matching ____________, made of one-quarter-wavelength transmission line, attached to a dipole antenna may be used to match transmission lines of various impedances to the antenna by connecting the line to the matching impedance point on the stub.

e. A ____________ is a device used to match a balanced system to an unbalanced system.

TRANSMISSION LINES
UNIT X

ANSWERS TO TEST

1. a. 3
   b. 5
   c. 6
   d. 2
   e. 4
   f. 8
   g. 1
   h. 7

2. To transfer maximum energy with minimum loss

3. a. 1
   b. 4
   c. 3
   d. 2
   e. 5
   f. 6

4. a. 5
   b. 4
   c. 3
   d. 2
   e. 1

5. a. Capacitance, inductance
   b. Size, spacing, dielectric
   c. Inductance, capacitance
   d. Cutoff
   e. Velocity

6. a. Reflected, standing
   b. Nonresonant
   c. Absorbed
   d. Resonant
   e. Standing

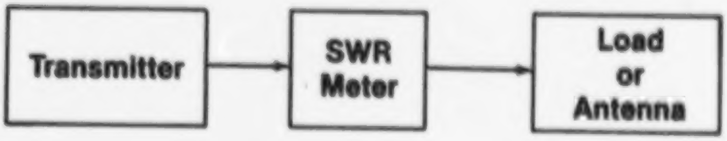
7. a. Capacitive reactance termination
   b. Inductive reactance termination
   c. Open termination
   d. Shorted termination

ANSWERS TO TEST

8. SWR = R_L / Z_O or $\frac{Z_O}{R_L}$

Also VSWR = Emax/Emin is acceptable

9.


Transmitter
SWR Meter
Load or Antenna

SWR meter is connected in series between transmitter and the antenna. SWR is read directly from the meter.

10. a. Transmission
b. Quarter
c. Delta
d. Stub
e. Balun

ANTENNAS AND PROPAGATION
UNIT XI

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify components of antennas and antenna arrays and determine their characteristics. Competencies will be demonstrated by completing the assignment sheets and the unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to antennas and propagation with their correct definitions.
2. Complete statements concerning basic functions of antennas.
3. Complete statements concerning the characteristics of electromagnetic waves.
4. Select true statements concerning polarization of electromagnetic waves.
5. Complete statements concerning the characteristics of antenna length.
6. Select true statements concerning the characteristics of a half-wave vertical antenna.
7. Complete statements concerning the characteristics of a quarter-wave vertical antenna.
8. Complete statements concerning the characteristics of antenna arrays.
9. Complete statements concerning the characteristics of parasitic arrays.
10. Select true statements concerning characteristics of driven arrays.

OBJECTIVE SHEET

11. Complete statements concerning types of radio waves.
12. Complete statements concerning the characteristics of tropospheric scatter.
13. Calculate antenna length. (Assignment Sheet #1)
14. Calculate the radio horizon for direct waves. (Assignment Sheet #2)

ANTENNAS AND PROPAGATION
UNIT XI

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Integrate the following activities throughout the teaching of this unit:

1. Show the large variety of antennas available in supply catalogs.
2. Show films and videotapes concerning radio wave propagation.
3. Tour the "antenna farm" of your local cable television company.
4. Show a commercial antenna and identify its components.
5. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

H. Give test.

I. Evaluate test.

J. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Electronic Communications*. Benton Harbor, MI: Heath Company, 1981.

B. Hardy, James K. *Electronic Communications Technology*. Englewood Cliffs, NJ: Prentice-Hall, 1986.

C. Kennedy, George. *Electronic Communication Systems*. Third Edition. New York: McGraw-Hill Book Company, 1985.

D. Schrader, Robert L. *Electronic Communication*. Fifth Edition. New York: McGraw-Hill Book Company, 1985.

ANTENNAS AND PROPAGATION
UNIT XI

INFORMATION SHEET

I. **Terms and definitions**

A. Antenna — A conductor or set of conductors used to radiate energy into space or collect energy from space

B. Antenna array — Antenna elements grouped to accomplish a specified gain and/or directivity

C. Balun — Device used for matching transmission lines to antennas

D. Dipole — A center-fed antenna commonly used for frequencies below thirty megahertz

E. Full-wave dipole — A dipole antenna that has a length equal to one wavelength of the operating frequency

F. Half-wave dipole — A dipole antenna that has a length equal to half the wavelength of the operating frequency

G. Induction field — A field that is associated with that portion of the electromagnetic wave that immediately surrounds the antenna

H. Marconi antenna — A one-fourth-wavelength antenna that uses reflected ground to provide the missing one-fourth-wavelength

I. Radiation field — That part of the electromagnetic wave that travels through space

J. Reflector — An element in a multielement antenna that reflects a signal to the driven element of the antenna

K. Tropospheric scatter — A little understood phenomena that refers to the scattering of a high power radio wave by irregularities in the earth's atmosphere

L. Wavelength — The distance between two successive peaks of a signal

M. Yagi antenna — A sharply directional antenna array commonly used for television reception

INFORMATION SHEET

II. **Basic functions of antennas**

A. A transmitting antenna converts RF currents produced by the transmitter into electromagnetic waves which can be radiated through space.

1. It may be considered a transducer because it converts current energy into electromagnetic waves.

2. Electromagnetic waves travel through space at approximately the speed of light.

B. The receiving antenna collects the transmitted energy and converts it back into RF currents.

1. When the receiving antenna collects the energy from space, a voltage is induced across the antenna.

2. RF current produced in antenna is transferred to the receiver circuits for amplification and processing.

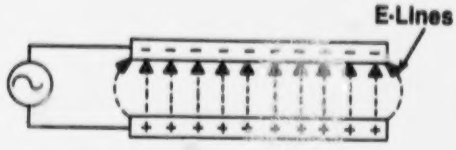
III. **Characteristics of electromagnetic waves** (Transparency 1)

A. An electromagnetic wave consists of two primary components.

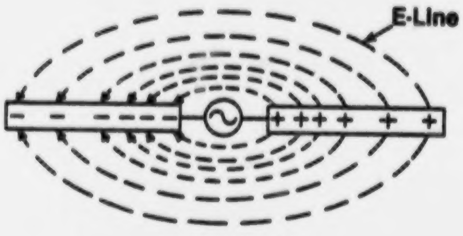
1. Electric field resulting from accumulation of charges

2. Magnetic field resulting from current flow

B. The electric field is usually represented graphically by lines called E-lines and is the result of the accumulation of charges on the conductors.



Parallel Rods

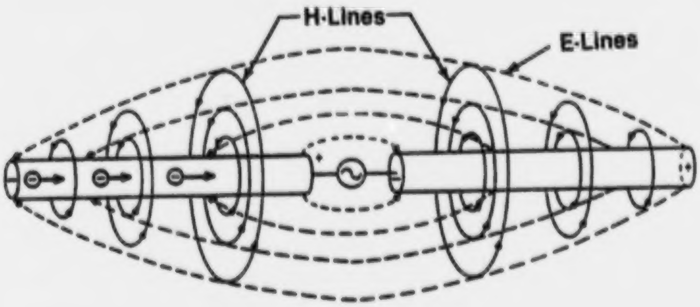


In-Line Rods

(NOTE: The generator connected between the two rods creates a difference of potential between the two rods and therefore an electric field exists between the two rods. The polarity of the rods and the direction of the electric fields will reverse polarity and direction periodically at the frequency of the voltage source.)

INFORMATION SHEET

C. The magnetic field is produced by current flow in the conductor and is represented graphically by H-lines.



D. The E and H lines are 90 degrees out of phase in time and at right angles to each other in space.

E. The electromagnetic field that is the result of the combination of the magnetic and electric lines of force may be divided into two parts: **induction field** and **radiation field.**

F. The **induction field** is associated with that portion of the electromagnetic wave that immediately surrounds the antenna and which collapses completely when the antenna voltage and current reverse.

  1. It is mainly responsible for the behavior of the antenna as a tuned circuit element.
  2. Energy is stored alternately in the magnetic and electric field immediately surrounding the antenna.
  3. Strength varies inversely as the square of the distance from the antenna.
  4. It is responsible for resonant effect reflected to the RF source.

G. The **radiation field** is associated with that part of the electromagnetic wave that is emitted from the antenna and travels through space.

  1. This varies inversely with the distance from the antenna.
  2. The energy contained in the radiation field is that which is intercepted by the receiving antenna.

IV. **Polarization of electromagnetic waves** (Transparencies 2 and 3)

  A. The position in which the electromagnetic waves radiate in respect to the earth is called polarization.

INFORMATION SHEET

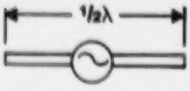
B. When an electromagnetic wave is transmitted so that its electric lines (E-lines) are horizontal (parallel) to the earth, the wave is horizontally polarized.

C. When the electric lines travel vertically to the earth, the wave is vertically polarized.

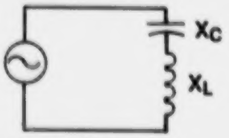
D. When constant amplitude electric lines of force are continuously changing their angular position, through 360 degrees, as they are radiated into space, the resulting effect is called circular polarization.

V. **Characteristics of antenna length**

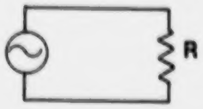
A. An antenna which is a multiple of one half-wavelength acts as a resonant circuit and appears as a pure resistive circuit.



Half-Wave Dipole



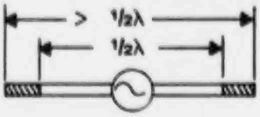
Series-Resonant Circuit



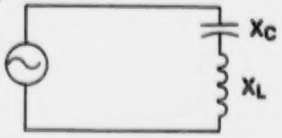
Appears Resistive to Input

B. Any antenna which is either longer or shorter than a multiple of one half-wavelength will oppose any current flow with an impedance composed of both resistance and reactance.

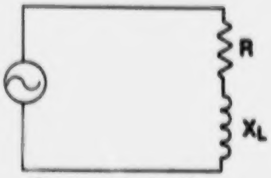
C. An antenna which is longer than some multiple of a half-wavelength will act as an inductive circuit.



Long Antenna

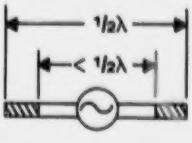


Series Circuit with X_L Predominant

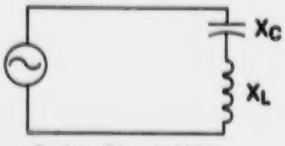


Appears Inductive to Input

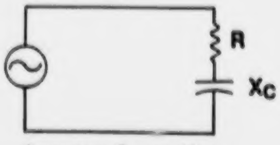
D. An antenna that is shorter than a multiple of a half-wavelength will act as a capacitive circuit.



Short Antenna



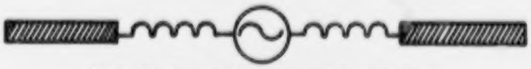
Series Circuit With X_C Predominant



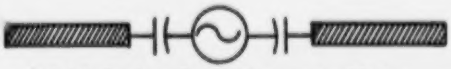
Appears Capacitive to Input

INFORMATION SHEET

E. An inductance added in series with the antenna will make the antenna appear electrically longer.



Add Series Inductance to Make Antenna Electrically Longer



Add Series Capacitance to Make Antenna Electrically Shorter

F. A capacitance added in series with the antenna will make the antenna appear electrically shorter.

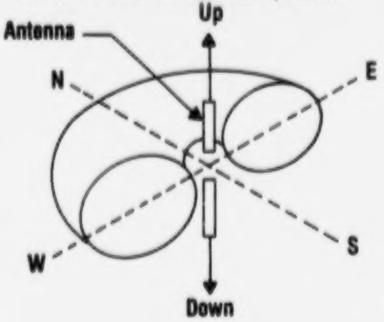
VI. **Characteristics of a half-wave dipole antenna**

A. The half-wave dipole is one of the most commonly used antennas.

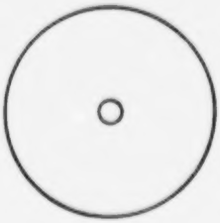
B. The half-wave dipole is one-half wavelength at operating frequency.

C. The pattern of radiation from an antenna is its most important property.

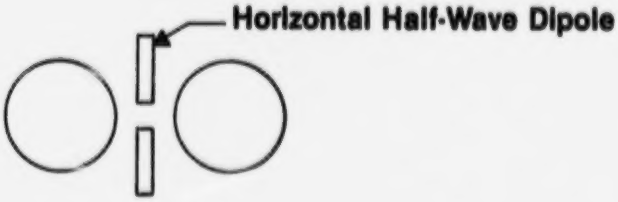
D. The maximum radiation of a **vertical** half-wave dipole occurs in all directions in the horizontal plane.



Cross Section

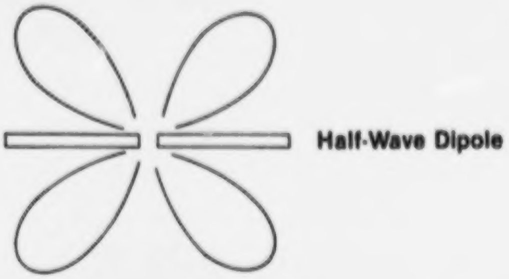


E. The maximum radiation from a **horizontal** half-wave dipole occurs broadside to the antenna and minimum radiation occurs from the ends.

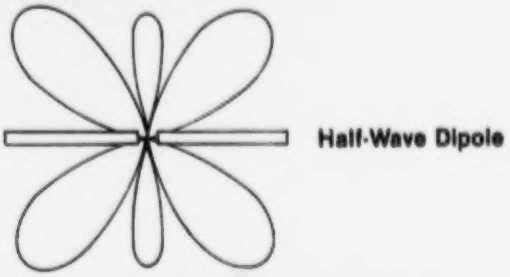


INFORMATION SHEET

F. If a half-wave dipole were operated at the second harmonic of its fundamental frequency it would perform as a full-wave dipole with full-wave radiation pattern.



G. If a half-wave dipole were operated at the third harmonic of its fundamental frequency it would perform as a $1\frac{1}{2}$-wavelength antenna with $1\frac{1}{2}$-wavelength, radiation characteristics.



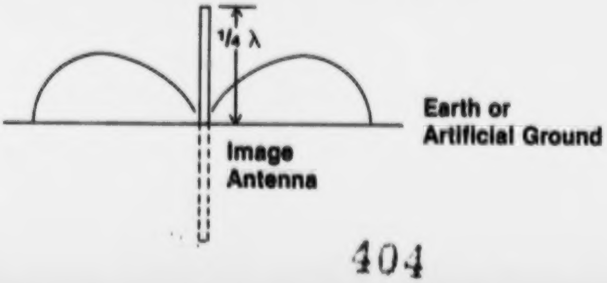
(NOTE: An example of dual usage of a half-wave dipole antenna is an antenna designed to operate on both the 7 MHz and 21 MHz amateur radio bands. It will operate as a half-wave dipole at 7 MHz and a $1\frac{1}{2}$-wavelength antenna at 21 MHz.)

VII. **Characteristics of a quarter-wave vertical antenna**

A. A $\frac{1}{4}$-wavelength, vertical antenna constructed above a perfect ground will have similar characteristics as the half-wave vertical dipole.

B. The perfect ground produces a "mirror image" of the quarter-wave giving the effect of a half-wave antenna.

(NOTE: If the antenna is constructed over soil with poor conductivity, an artificial ground must be constructed to give the desired effect.)



INFORMATION SHEET

C. Radiation is omnidirectional and has good long distance propagation characteristics.

D. Input impedance is approximately 36 ohms when used with a perfect ground.

E. When fed with an unbalanced coaxial conductor, the shield is connected to the ground or artificial ground system, and the center conductor is connected to the antenna.

VIII. **Characteristics of antenna arrays**

A. Antenna arrays provide for directivity and directional gain in antenna systems.

1. Increase efficiency of radiated power.

2. Directional gain is the ratio of the power required to produce a given field strength to power required to produce the same field strength in a directional antenna system.

B. Combinations of two or more antenna elements form an antenna array.

C. Antenna system elements are classified as driven or parasitic arrays depending on the method used to excite the elements.

D. A driven element is excited directly by the transmitter via a transmission line.

E. A parasitic element is excited through induction from a driven element in the array.

F. A driven array is an antenna system in which all elements are driven elements.

G. A parasitic array is an antenna system in which one or more of the elements is a parasitic element.

IX. **Characteristics of parasitic arrays** (Transparency 4)

A. Parasitic arrays contain elements called directors and reflectors.

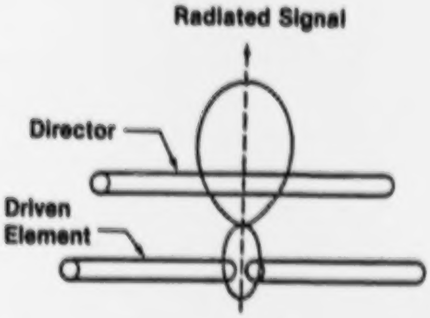
B. A parasitic element which reinforces radiation from the driven element in the direction of the parasitic element is called a director.

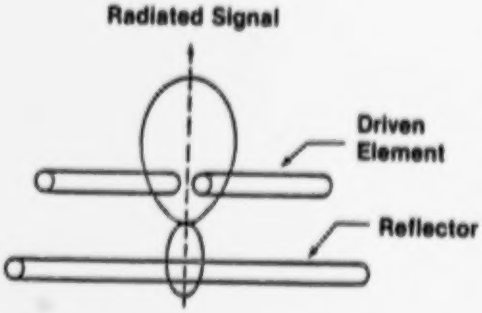
(NOTE: The driven element is commonly a ½-wavelength dipole.)

1. A director is approximately 5 percent shorter a than driven element.

INFORMATION SHEET

2. Spacing between director and driven element is approximately two-tenths wavelength.


Radiated Signal
Director
Driven Element


Radiated Signal
Driven Element
Reflector

C. If the parasitic element is placed so that is causes maximum radiation from itself toward the driven element, it is called a reflector.

  1. A reflector is approximately five percent longer than the driven element.

  2. A reflector is spaced approximately one-tenth wavelength from the driven element.

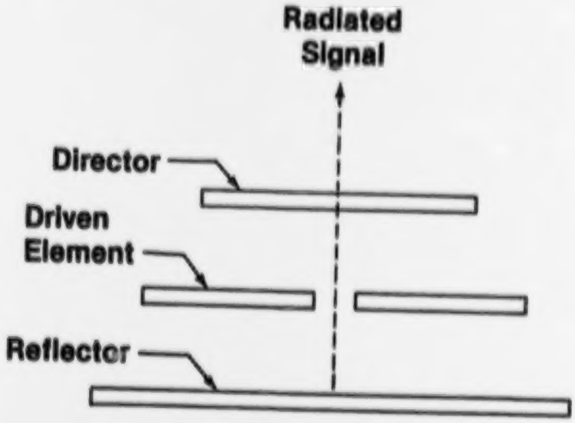
D. The directivity pattern which results from the action of parasitic elements depends on two factors.

  1. Tuning determined by the length of the parasitic element

  2. Spacing between the parasitic and driven elements

E. A Yagi antenna is an example of a parasitic array having both a reflector and a director.

(NOTE: More directors may be added to obtain even more directivity and directional gain.)


Radiated Signal
Director
Driven Element
Reflector

INFORMATION SHEET

X. **Characteristics of driven arrays**

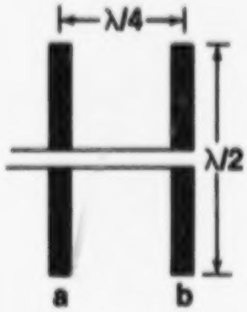
A. An antenna system is considered to be a driven array when all the elements are fed (or driven) by the transmission line.

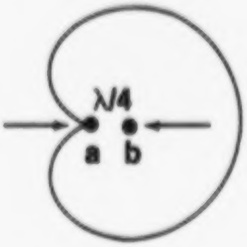
B. Two common driven arrays are called the cardioid and co-linear.

C. A cardioid array is one where two dipoles are spaced one-quarter wavelength apart and are excited ninety degrees out of phase.

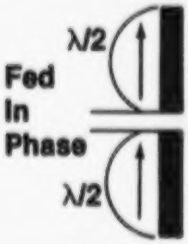
1. Unidirectional radiation pattern

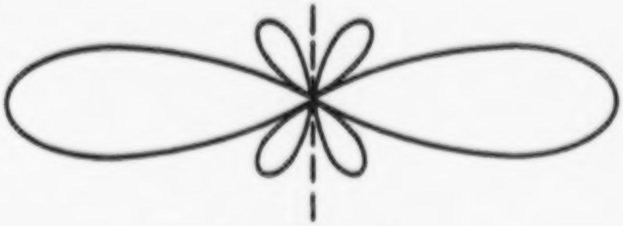
2. Radiation pattern is heart-shaped, therefore the name cardioid





D. A co-linear array is one where two half-wave elements are placed end to end and excited in-phase.





Four Elements

XI. **Types of radio waves**

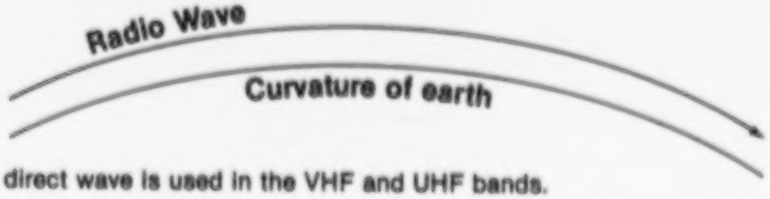
A. A radio wave that travels along the surface of the earth is known as a ground wave.

1. Predominant mode of propagation at low and medium frequencies

2. The longer wavelengths of the lower frequencies tend to follow the curvature of the earth

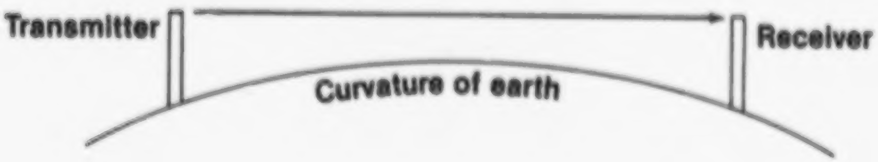
INFORMATION SHEET

3. At higher frequencies, ground waves are attenuated or broken up by obstructions such as buildings, trees, and hills


Radio Wave
Curvature of earth

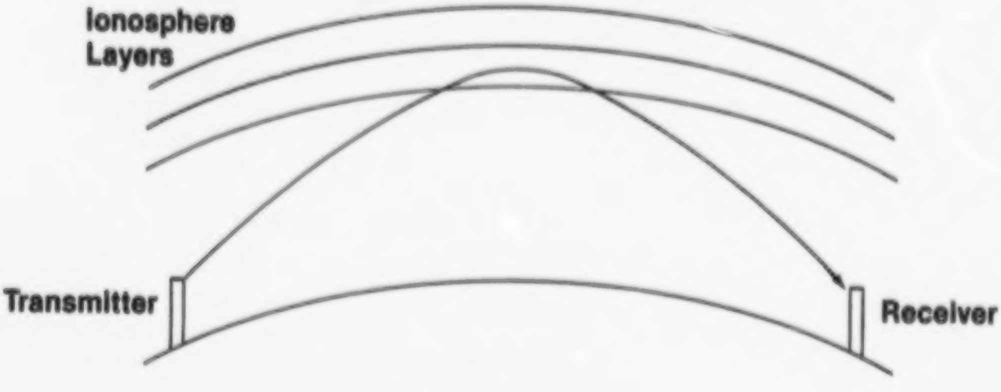
B. The direct wave is used in the VHF and UHF bands.

1. Usable only for "line-of-sight" distances
2. Antenna height effects range of transmission
3. Used to transmit to and from satellites and aircraft


Transmitter
Receiver
Curvature of earth

C. A direct wave which has been refracted back to earth by the ionosphere is called a sky wave.

1. Most propagation on the high frequency (HF) band is by sky wave.
2. Ionospheric variations and sun spots can affect sky waves.


Ionosphere
Layers
Transmitter
Receiver

INFORMATION SHEET

XII. Characteristics of tropospheric scatter

A. The range of VHF and UHF may be extended by tropospheric scatter communications and satellite communications.

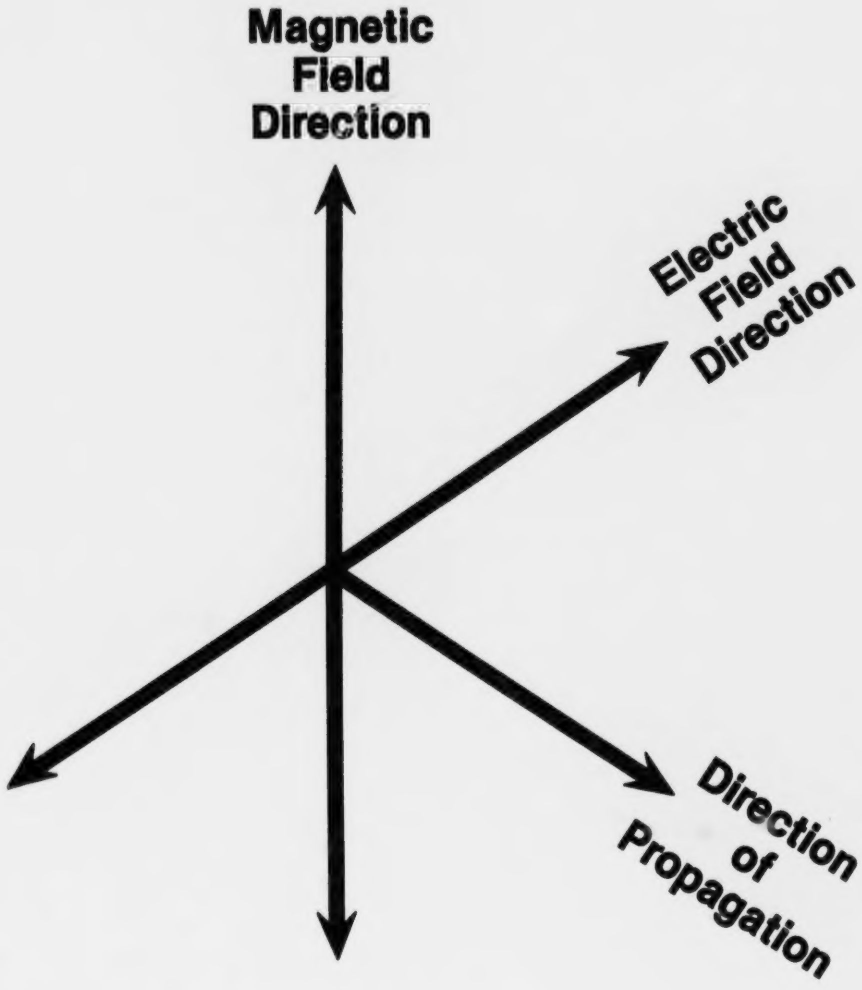
B. High power transmitter is required.

C. High gain receiver is required.

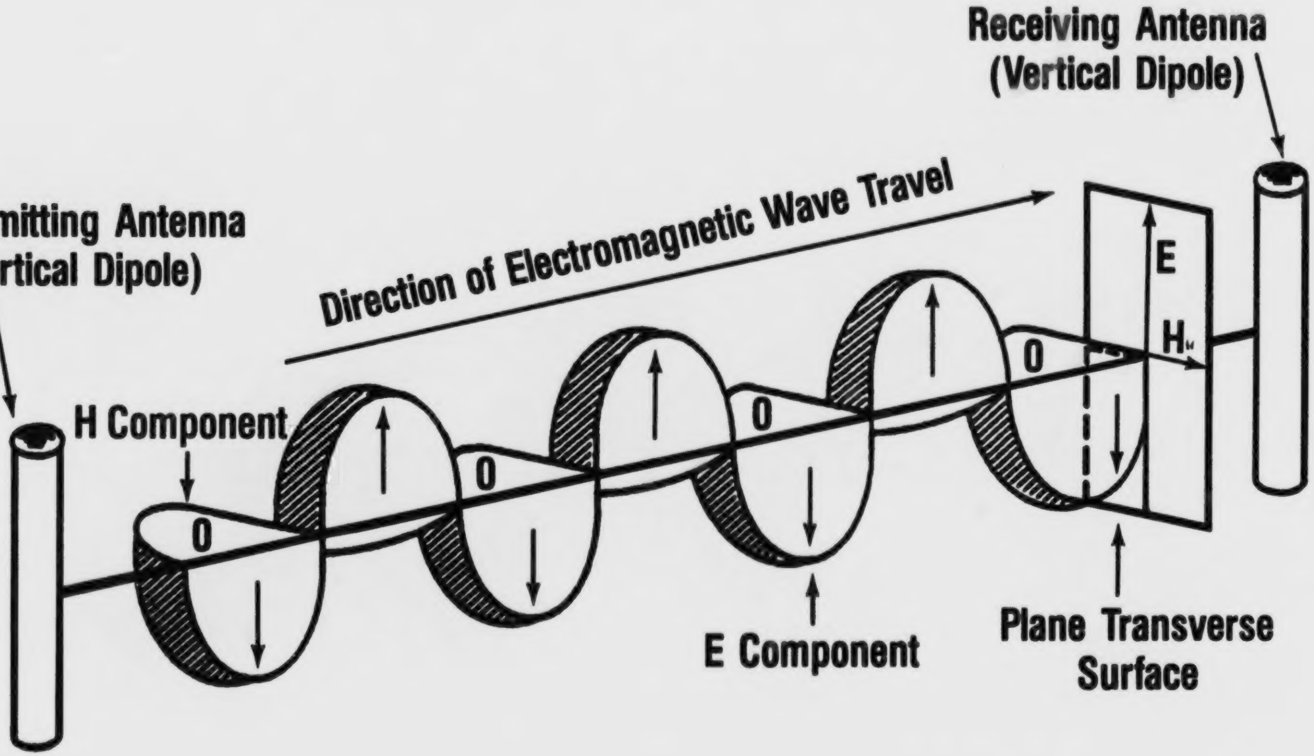
D. System is usually costly and used only for special purposes.

(NOTE: A tropospheric scatter system is used almost exclusively for communications to offshore oil drilling rigs in the North Sea.)

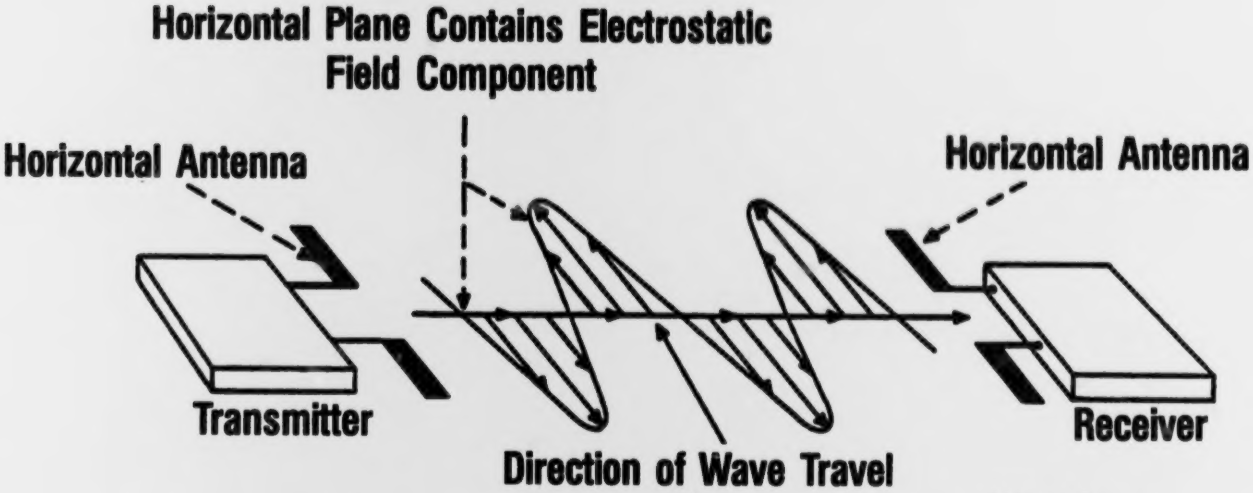
Electromagnetic Wave


Magnetic Field Direction
Electric Field Direction
Direction of Propagation

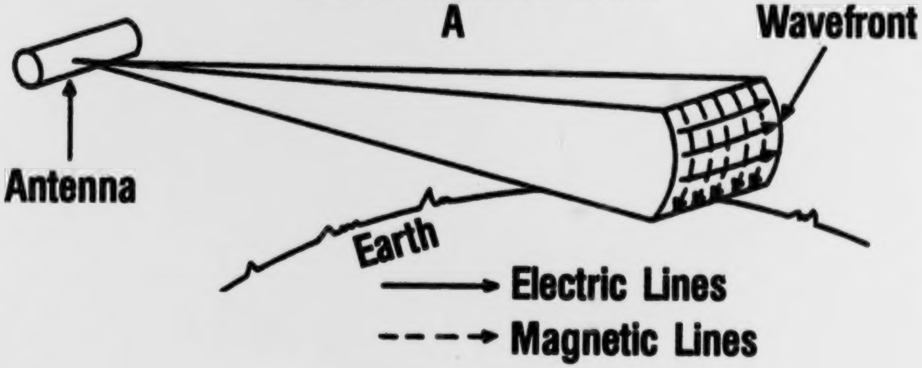
E and H Fields of a Radiated Wave


Receiving Antenna
(Vertical Dipole)
Transmitting Antenna
(Vertical Dipole)
Direction of Electromagnetic Wave Travel
E
H
H Component
0
0
0
0
E Component
Plane Transverse
Surface

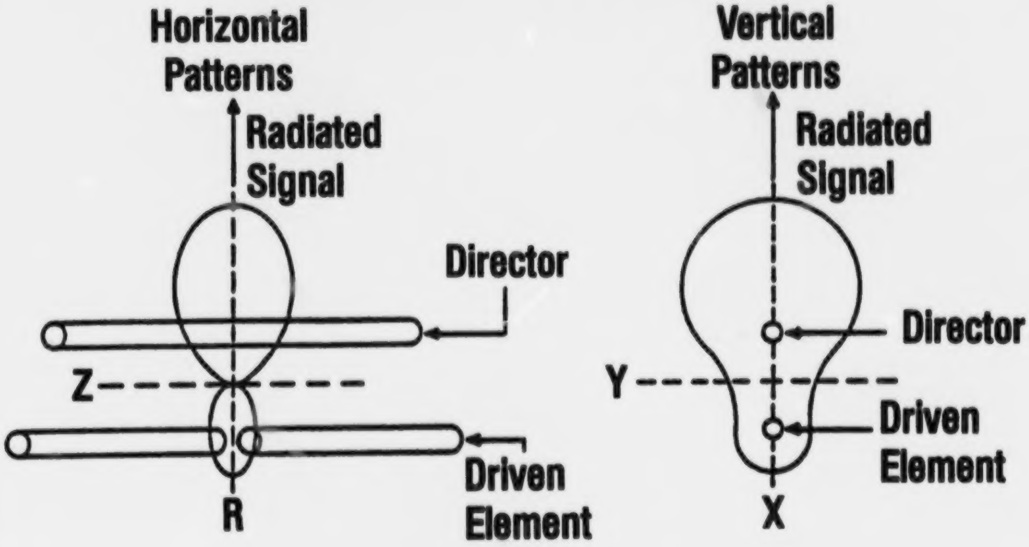
Electromagnetic Waveform


Horizontal Plane Contains Electrostatic Field Component
Horizontal Antenna
Horizontal Antenna
Transmitter
Receiver
Direction of Wave Travel

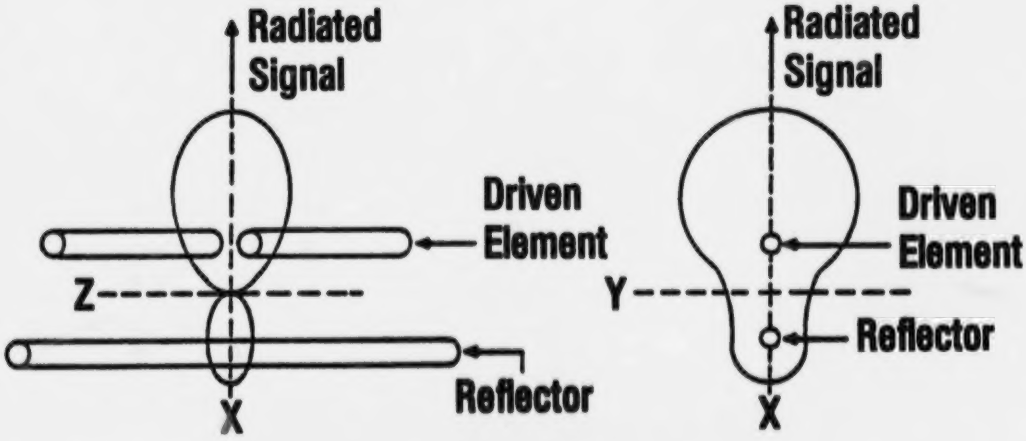
A


Wavefront
Antenna
Earth
Electric Lines
Magnetic Lines

Radiation Patterns Using Parasitic Elements


Horizontal Patterns
Radiated Signal
Director
Z
Driven Element
R
Vertical Patterns
Radiated Signal
Director
Y
Driven Element
X

Patterns Obtained Using Director


Radiated Signal
Driven Element
Z
Reflector
X
Radiated Signal
Driven Element
Y
Reflector
X

Patterns Obtained Using Reflector

ANTENNAS AND PROPAGATION
UNIT XI

ASSIGNMENT SHEET #1 — CALCULATE ANTENNA LENGTH

NAME ____________________ SCORE ____________________

Introduction: Length of an antenna is related to the wavelength of the frequency being transmitted or received. Wavelength varies inversely as the frequency and is determined by the formula:

$$\lambda = v/f$$

Where λ = wavelength
v = velocity (300,000,000 meters/sec)
f = frequency in Hz

An antenna develops "end effect" which makes the antenna appear electrically as though it were about 5% longer than its actual length. The above formula may be converted to take into account the 5% and replace meters with feet. When converted, the formula for a one-half wavelength dipole antenna is:

$$\tfrac{1}{2}\lambda \text{ in feet} = 468/f \text{ (in MHz)}$$

Directions: Use the formula given above to calculate the length of the antennas in the following problems.

1. Calculate the length of a half-wave dipole for a frequency of 7 MHz.____________

   ____

2. What is the length of a half-wave dipole operated at a frequency of 10 MHz?________

   ____

ANTENNAS AND PROPAGATION
UNIT XI

ASSIGNMENT SHEET #2 — CALCULATE THE RADIO HORIZON FOR DIRECT WAVES

NAME ____________________ SCORE ____________________

Introduction: The radio horizon for direct waves (line-of sight) is about one and one-third as far as the optical horizon due to refraction in the earth's lower atmosphere. The radio horizon of a transmitting antenna is found by using the formula:

$$Dt = 4\sqrt{Ht}$$

Where Dt = radio horizon of transmitting antenna in kilometers (Km)
Ht = height of transmitting antenna in meters

The formula may also be used for the receiving antenna:

$$Dr = 4\sqrt{Hr}$$

Where Dr = radio horizon of receiving antenna in kilometers (Km)
Hr = height of receiving antenna

The radio horizon between transmitting antenna and receiving antenna must take into account the radio horizon of each and may be found by the formula:

$$Dm = Dt + Dr = 4\sqrt{Ht} + 4\sqrt{Hr}$$

Dm equals the maximum direct wave distance between two antennas.

Directions: Use the formulas above to solve the following problems.

1. A transmitting antenna has a height of 100 meters and a receiving antenna height of 49 meters. What is the maximum direct wave communications distance between the two antennas? ____________________

   ____

2. A transmitting antenna has a height of 64 meters and a receiving antenna height of 81 meters. What is the maximum direct wave communications distance between the two antennas? ____________________

   ____

ANTENNAS AND PROPAGATION
UNIT XI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

1. 66.9 feet
2. 46.8 feet

Assignment Sheet #2

1. 68 Km
2. 68 Km

ANTENNAS AND PROPAGATION
UNIT XI

TEST

NAME ______________________ SCORE ______________________

1. Match the terms on the right with their correct definitions.

______a. A conductor or set of conductors used to radiate energy into space or collect energy from space

______b. A device used for matching transmission lines to antennas

______c. A center-fed antenna commonly used for frequencies below thirty megahertz

______d. A dipole antenna that has a length equal to half the wavelength of the operating frequency

______e. A dipole antenna that has a length equal to one wavelength of the operating frequency

______f. A field that is associated with that portion of the electromagnetic wave that immediately surrounds the antenna

______g. That part of the electromagnetic wave that travels through space

______h. Antenna elements grouped to accomplish a specified gain and/or directivity

______i. An element in a multielement antenna that reflects a signal to the driven element of the antenna

______j. The distance between two successive peaks of a signal

______k. A one-fourth wavelength antenna that uses reflected ground to provide the missing one-fourth wavelength

1. Antenna
2. Antenna array
3. Balun
4. Dipole
5. Full-wave dipole
6. Half-wave dipole
7. Induction field
8. Marconi antenna
9. Radiation field
10. Reflector
11. Tropospheric scatter
12. Wavelength
13. Yagi antenna

TEST

_____l. A sharply directional antenna array commonly used for television reception

_____m. A little understood phenomena that refers to the scattering of a high power radio wave by irregularities in the earth's atmosphere

2. Complete the following statements concerning basic functions of antennas by inserting the word that best completes each statement.

   a. A __________ antenna converts RF currents produced by the transmitter into electromagnetic waves which can be radiated through space.

   b. Electromagnetic waves travel through space at approximately the speed of __________.

   c. The __________ antenna collects the transmitted energy and converts it back into RF currents.

3. Complete the following statements concerning the characteristics of electromagnetic waves by inserting the word(s) that best complete(s) each statement.

   a. An electromagnetic wave consists of two primary components: an __________ field and a __________ field.

   b. The electric field is usually represented graphically by lines called E-lines and is the result of the accumulation of __________ on the conductors.

   c. The magnetic field is produced by __________ flow in the conductor and is represented graphically by H-lines.

   d. The E and H lines are __________ degrees out of phase in time and at right angles to each other in space.

   e. The __________ field that is the resultant of the combination of the magnetic and electric lines of force may be divided into two parts: __________ __________ and the __________ __________.

   f. The __________ field is associated with that portion of the electromagnetic wave that immediately surrounds the antenna and which collapses completely when the antenna voltage and current reverse.

   g. The induction field is mainly responsible for the behavior of the antenna as a __________ circuit element.

   h. The strength of the induction field varies inversely as the square of the __________ from the antenna.

TEST

i. The ____________ field is associated with that part of the electromagnetic wave that is emitted from the antenna and travels through space.

j. The strength of the radiation field varies inversely with the ____________ from the antenna.

4. Select true statements concerning polarization of electromagnetic waves by placing an "X" in the blanks preceding the true statements.

_____a. The position in which the electromagnetic waves radiate in respect to the earth is called polarization.

_____b. When an electromagnetic wave is transmitted so that its electric lines (E-lines) are horizontal (parallel) to the earth, the wave is horizontally polarized.

_____c. When the electric lines travel vertically to the earth, the waves are vertically polarized.

_____d. Constant amplitude electric lines of force that are continuously changing their angular position, through 360 degrees, as they are radiated into space have circular polarization.

5. Complete the following statements concerning the characteristics of antenna length by inserting the word that best completes each statement.

a. An antenna which is a multiple of one half-wavelength acts as a resonant circuit and appears as a pure ____________ circuit.

b. Any antenna which is either longer or shorter than a multiple of one half-wavelength will oppose any current flow with an impedance composed of both resistance and ____________ .

c. An antenna which is longer than some multiple of a half-wavelength will act as an ____________ circuit.

d. Any antenna that is shorter than a multiple of a half-wavelength will act as a ____________ circuit.

e. An inductance added in series with the antenna will make the antenna appear electrically ____________ .

f. A capacitance added in series with the antenna will make the antenna appear electrically ____________ .

TEST

6. Select true statements concerning the characteristics of a half-wave dipole antenna by placing an "X" in the blanks preceding the true statements.

_____a. The half-wave dipole is one of the most commonly used antennas.

_____b. The half-wave dipole is the least used of the antenna types.

_____c. The half-wave dipole is one wavelength at operating frequency.

_____d. The pattern of radiation from an antenna is its most important property.

_____e. The maximum radiation of a **vertical** half-wave dipole occurs in all directions in the horizontal plane.

_____f. The maximum radiation from a **horizontal** half-wave dipole occurs broadside to the antenna and minimum radiation occurs from the ends.

_____g. If a half-wave dipole were operated at the second harmonic of its fundamental frequency it would perform as a full-wave dipole with full-wave radiation pattern.

_____h. If a half-wave dipole were operated at the third harmonic of its fundamental frequency it would perform as a 1½-wavelength antenna with 1½-wavelength radiation characteristics.

7. Complete the following statements concerning the characteristics of a quarter-wave vertical antenna by inserting the word that best completes each statement.

a. A ¼-wavelength, vertical antenna constructed above a perfect ground will have similar characteristics as the _____ - _____ vertical dipole.

b. The perfect ground produces a "mirror image" of the quarter-wave giving the effect of a _____ - _____ antenna.

c. ___________ is omnidirectional and has good long distance propagation characteristics.

d. Input ___________ is approximately 36 ohms when used with a perfect ground.

e. When fed with an unbalanced coaxial conductor, the shield is connected to the ground or artificial ground system, and the center conductor is connected to the ___________.

TEST

8. Complete the following statements concerning the characteristics of antenna arrays by inserting the word that best completes each statement.

   a. Antenna arrays provide for ____________ and directional gain in antenna systems.

   b. Combinations of two or more antenna ____________ form an antenna array.

   c. Antenna system elements are classified as ____________ or ____________ arrays depending on the method used to excite the elements.

   d. A ____________ element is excited directly by the transmitter via a transmission line.

   e. A ____________ element is excited through induction from a driven element in the array.

   f. A driven array is an antenna system in which all elements are ____________ elements.

   g. A parasitic array is an antenna system in which one or more of the elements is a ____________ element.

9. Complete the following statements concerning the characteristics of parasitic arrays by inserting the word(s) that best complete(s) each statement.

   a. Parasitic arrays contain elements called ____________ and ____________.

   b. A parasitic element which reinforces radiation from the driven element in the direction of the parasitic element is called a ____________.

   c. A director is approximately ____________ percent shorter than the driven element.

   d. If the parasitic element is placed so that it causes maximum radiation from itself toward the driven element, it is called a ____________.

   e. A ____________ is approximately five percent longer than the driven element.

   f. A ____________ antenna is an example of a parasitic array having both a reflector and a director.

10. Select true statements concerning characteristics of driven arrays by placing an "X" in the blanks preceding the true statements.

   ______a. An antenna system is considered to be a driven array when all the elements are fed by the transmission line.

   ______b. Two common driven arrays are called the cardioid array and the co-linear array.

TEST

_____c. A cardioid is an array where two dipoles are spaced one-quarter wavelength apart and are excited ninety degrees out of phase, and exhibit a unidirectional radiation pattern that is heart-shaped.

_____d. A co-linear array is one where two half-wave elements are placed end to end and excited in-phase.

11. Complete the following statements concerning types of radio waves by inserting the word that best completes each statement.

    a. A radio wave that travels along the curvature of the earth's surface is known as a ____________ wave.

    b. A ____________ wave is used in the VHF and UHF band and is transmitted over "line-of-sight" distances between points on the earth's surface or between satellites, aircraft, and earth stations.

    c. A direct wave which has been refracted back to earth by the ionosphere is called a ____________ wave.

12. Complete the following statements concerning characteristics of tropospheric scatter by inserting the word(s) that best complete(s) each statement.

    a. The range of VHF and UHF may be extended by tropospheric scatter communications and ____________ communications.

    b. High power ____________ is required.

    c. High gain ____________ is required.

    d. System is usually ____________ and used only for special purposes.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Calculate antenna length. (Assignment Sheet #1)

14. Calculate the radio horizon for direct waves. (Assignment Sheet #2)

ANTENNAS AND PROPAGATION
UNIT XI

ANSWERS TO TEST

1. a. 1
   b. 3
   c. 4
   d. 6
   e. 5
   f. 7
   g. 9
   h. 2
   i. 10
   j. 12
   k. 8
   l. 13
   m. 11

2. a. Transmitting
   b. Light
   c. Receiving

3. a. Electric, magnetic
   b. Charges
   c. Current
   d. 90
   e. Electromagnetic
   f. Induction
   g. Tuned
   h. Distance
   i. Radiation
   j. Distance

4. a, b, c, d

5. a. Resistive
   b. Reactance
   c. Inductive
   d. Capacitive
   e. Longer
   f. Shorter

6. a, d, e, f, g, h

7. a. Half-wave
   b. Half-wave
   c. Radiation
   d. Impedance
   e. Antenna

8. a. Directivity
   b. Elements
   c. Driven, parasitic
   d. Driven
   e. Parasitic
   f. Driven
   g. Parasitic

ANSWERS TO TEST

9. a. Directors, reflectors
   b. Director
   c. 5
   d. Reflector
   e. Reflector
   f. Yagi

10. a, b, c, d

11. a. Ground
   b. Direct
   c. Sky

12. a. Satellite
   b. Transmitter
   c. Receiver
   d. Costly

13.-14. Evaluated to the satisfaction of the instructor

TWO-WAY COMMUNICATIONS
UNIT XII

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify components, perform tests, and install antennas and transceivers in two-way communication systems. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to two-way communications with their correct definitions.
2. Match abbreviations related to communication systems with their correct definitions.
3. List six two-way radio services.
4. Complete statements concerning types of microphones.
5. Select true statements related to a basic FM communications system.
6. Distinguish between the characteristics of remote relay and repeater stations.
7. Select from a list characteristics of pagers.
8. Complete statements concerning transmitter measurements.
9. List four types of receiver checks.
10. Match major test instruments used for checking communication systems with their correct uses.

OBJECTIVE SHEET

11. Complete statements concerning characteristics of trunked and cellular systems.
12. Complete statements concerning considerations for interfacing to telephone lines.
13. Demonstrate the ability to:
    a. Install a two-way mobile radio. (Job Sheet #1)
    b. Install a two-way mobile antenna. (Job Sheet #2)

TWO-WAY COMMUNICATIONS
UNIT XII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparency from the transparency master included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparency to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

   1. Show examples of two-way communication systems.

   2. Invite representatives from industry to speak to class about two-way communication systems.

   3. Demonstrate how to test, measure, and adjust two-way communication units.

   4. Visit two-way communication installations.

   5. Show examples of communications test equipment and demonstrate their use.

   6. Visit a repeater site.

   7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. *Electronic Communications*. Benton Harbor, MI: Heath Company, 1981.

B. Hardy, James K. *Electronic Communications Technology*. Englewood Cliffs, NJ: Prentice-Hall, 1986.

C. Kennedy, George. *Electronic Communication Systems*. Third Edition. New York: McGraw-Hill Book Company, 1985.

D. Schrader, Robert L. *Electronic Communication*. Fifth Edition. New York: McGraw-Hill Book Company, 1985.

TWO-WAY COMMUNICATIONS
UNIT XII

INFORMATION SHEET

I. **Terms and definitions**

   A. Attenuator — A device that absorbs energy, thus reducing the power level

   B. Combiner — A device that allows the simultaneous transmission of two signals in the same channel without interaction

   C. De-emphasis circuit — A circuit used in the audio section of an FM receiver to attenuate high frequencies

   D. Dummy load — A device that simulates all the electrical characteristics of an antenna except that the energy supplied to it is not radiated

   E. Duplexer — A device that couples the receiver and transmitter to a common antenna

   F. Pre-emphasis circuit — A circuit used in an FM transmitter to amplify the high frequencies

   G. Selectivity — The ability of a receiver to accept a signal and reject adjacent signals

   H. Sensitivity — Defines the weakest signal that can be received

II. **Abbreviations related to communication systems**

   A. PTT — Push To Talk

   B. CTCSS — Continuous Tone Coded Squelch System

   C. PEP — Peak Envelope Power

   D. SSB — Single Sideband

   E. VF — Voice Frequency

   F. SINAD — Signal Including Noise And Distortion

III. **Two-way radio services**

   A. Citizens' band

   B. Amateur radio

   C. Aeronautical

INFORMATION SHEET

D. General mobile radio service

E. Private land mobile radio service

F. Domestic landline mobile radio service

IV. **Types of microphones**

A. Magnetic microphones operate on a principle of sound waves striking a diaphragm producing a relative movement between a magnetic field and a conductor, inducing a voltage in the conductor.

1. Dynamic microphone
2. Sound-powered microphone
3. Variable-reluctance, ribbon, or velocity

B. Crystal microphones convert sound into electrical signals when a diaphragm, mechanically connected to a crystal, is caused to vibrate producing stress on a crystal which in turn produces an AC signal.

C. Condenser (capacitor) microphones produce an electrical current through a capacitance that varies in synchronization with sound waves striking a diaphragm.

V. **Basic FM communications system**

A. The purpose of a two-way electronic communications system is to both transmit and receive intelligence via electronic means.

B. Both a transmitter and a receiver is present at each operator location.

C. When transmitter and receiver are contained within a single package as in a mobile radio, the unit is called a transceiver.

D. The transceiver is in the receive mode when operating unless the push-to-talk switch on the microphone is depressed.

E. The PTT switch activates a transmit-receive (TR) relay which changes the operation from receive to transmit.

F. Oscillator is crystal controlled for accuracy and stability of frequency of operation.

1. More than one crystal may be used if multiple frequencies are used in the communications system.
2. Oscillator circuits may be tuned to adjust for slight frequency variations.

INFORMATION SHEET

G. A pre-emphasis circuit is used in the transmitter to emphasize the higher audio-frequencies to prevent loss during transmission.

H. A de-emphasis circuit is used in the receiver to de-emphasize the higher audio frequencies before they are reproduced in the speaker.

I. CTCSS circuits provide for selective calling in services having many units but where only one or one group of units is to be called.

J. When only one antenna is used for simultaneous transmitting and receiving, two or more resonant cavities may be used in combiner circuits that prevents the transmitted signal on one frequency from interfering with the received signal on another nearby frequency.

K. The frequency tolerance and spectrum for operating units is specified by the FCC. (Transparency 1)

VI. **Characteristics of remote relay and repeater stations**

A. A remote station is a transceiver unit which usually operates on a fixed frequency receiving a signal, amplifying it, and then transmitting the signal on the same frequency.

1. Connected to control point by telephone lines or microwave link
2. The receiver or transmitter is operating, but not both
3. Usually located atop a high peak or building

B. A repeater station will receive one frequency and relay its received information to a transmitter which simultaneously radiates the information on another frequency.

1. Safety and remote control circuits are usually built-in to allow for unattended operation.
2. The transmitter and receiver operate simultaneously.

VII. **Characteristics of pagers**

A. Shirt, pocket-sized receiver

B. Tone activated from base station

C. Microprocessor controlled capabilities

D. Voice messages may be given

INFORMATION SHEET

VIII. **Transmitter measurements**

A. Frequency check is made using an NBS frequency counter.

1. Dummy load is connected to transmitter output.

2. Modulation should not be present during check.

(NOTE: SSB transmitters will need a stable AF modulating frequency to generate a sideband for measurement.)

3. Adjustment to frequency is made by tuning the oscillator circuit; large variations in frequency may indicate a more serious problem.

4. NBS standard frequency counter is connected after the dummy load using a 20 dB attenuator pad

(NOTE: Consult operation manual for proper connecting procedure).

B. Spurious signal check is made to detect unwanted signals.

1. Modulation should be present.

2. A spectrum analyzer connected across a dummy load may be used.

3. Adjust frequency traps to eliminate or reduce spurious signals.

C. Modulation checks are made to determine the percent of modulation and to detect distortion of modulating signal.

1. A high-quality oscilloscope may be used for AM systems.

2. A spectrum analyzer may be used in FM and PM systems to determine if upper and lower sidebands are symmetrical.

D. DC power input may be determined by measuring the average current drawn by the final stage and multiplying it by the average power supply voltage.

E. RF power output (PEP for SSB) may be determined using an RF wattmeter to measure power being sent to a dummy load.

IX. **Types of receiver checks**

A. **Selectivity** of a receiver may be checked by using a sweep generator and an oscilloscope.

1. Sweep generator connected to antenna terminals

2. Oscilloscope connected to demodulator output or to other points using a demodulator probe

INFORMATION SHEET

B. **Sensitivity** checks are best completed using a SINAD meter.

C. **Audio distortion** checks may be made using a distortion analyzer.

D. **Squelching threshold** is adjusted by rotating the squelch control with no signal applied until the receiver is no longer muted.

X. **Major test instruments used for checking communication systems**

A. Dummy load — Used to replace the antenna for testing purposes

B. Calibrated RF and AF signal generators — Used to inject standard frequencies

C. Distortion analyzer — Used to check VF distortion

D. RF wattmeter/SWR meter — Used to determine standing wave ratio and power output

E. RF ammeter — Used to check RF output current

F. Spectrum analyzer — Used to measure sidebands and spurious signals

G. Calibrated oscilloscope or modulation monitor — Used to check percentage of modulation, and peak envelope power (PEP).

H. Regulated power supply — Used to supply stable power to transmitter

I. SINAD (Signal Including Noise And Distortion) meter — A type of distortion analyzer consisting of a multi-range AF voltmeter calibrated in dB and a 1000-Hz bandstop filter used to check quieting and sensitivity

J. Communications monitor — A unit consisting of multiple test instruments capable of analyzing communication systems

K. Frequency counter — Used to check output frequency of transmitter

XI. **Characteristics of trunked and cellular systems**

A. A trunked system allows for the sharing of frequency channels by multiple users of the multi-channel system.

B. A trunked system uses a control channel or computers to scan for open channels.

C. A digital burst is used to identify users with an open but private channel in modern systems.

D. Cellular systems operate similar to trunked systems in that they switch mobile units between multiple repeaters in a cellular system to maintain the strongest possible signal.

INFORMATION SHEET

XII. **Considerations for interfacing to telephone lines**

A. Ringing voltages of 90 volts can cause damage to electronic circuits.

B. Subscriber telephone lines have up to 48 volts DC across them at all times.

C. Use only approved acoustical couplers or modems.

D. Line level of audio should not exceed 0 DBm when read across 600 ohm telephone line.

E. "Cross-talk" to lines running in a common cable may be caused by signals greater than 0 DBm.

F. DC control voltages can exceed 260 volts.

Frequencies and Tolerances

	Fixed and Base stations		Mobile stations	
Frequency range MHz	Over 200-W output, %	200-W output or less, %	Over 2-W output, %	2-W output and less, %
Below 25	0.005	0.01	0.01	0.02
USB J3E	50 Hz	50 Hz	50 Hz	50 Hz
25-50	0.002	0.002	0.002	0.005
50-450	0.0005	0.0005	0.0005	0.005
450-512	0.00025	0.00025	0.0005	0.0005
806-866	0.00015	0.00015	0.00025	0.00025
1427-1435	0.03	0.03	0.03	0.03

TWO-WAY COMMUNICATIONS
UNIT XII

JOB SHEET #1 — INSTALL A TWO-WAY MOBILE RADIO

A. Equipment and materials needed

1. Two-way radio unit
2. Installation and operation manual for two-way unit
3. Mounting bracket
4. Standard service tool kit
5. Portable electric drill

B. Procedure

1. Select location which provides easy access for servicing.
2. Check mounting bracket for fit; refabricate if necessary.
3. Drill holes if necessary and install mounting bracket.

   (NOTE: If location involves mounting on carpet, do not drill directly through carpet, cut a small "X" access in the carpet, and fold flaps back. Avoid areas having other operating components such as hydraulic lines, electrical wires, and fuel tank.)

4. Install transmitter/receiver unit on mounting plate.
5. Connect power and antenna cables.
6. Lock unit in place.
7. Evaluate transceiver for proper operation.
8. Clean-up residue that may have accumulated during installation and leave unit neat in appearance.
9. Have instructor check your work.
10. Proceed to Job Sheet #2 and install a two-way mobile antenna.

TWO-WAY COMMUNICATIONS
UNIT XII

JOB SHEET #2 — INSTALL A TWO-WAY MOBILE ANTENNA

A. Equipment and materials needed

1. Two-way radio antenna
2. Installation instructions for selected antenna
3. Mounting hardware and cable
4. Standard service tool kit
5. Portable electric drill
6. SWR meter

B. Procedure

1. Select antenna location which considers the following factors:
    a. Possible damage to the vehicle when in operation
    b. Possible damage to the antenna when the vehicle is in operation
    c. Manufacturer's recommended minimum distance from fixed object on vehicle
    d. Location of vehicle vital parts such as fuel tanks or electrical harness
    e. Customer preference
2. Drill mounting hole.
3. Scrape approximately 1/16" of paint from around the hole to insure a good ground.
4. Determine the best cable route and run fish tape between antenna location and transceiver unit.
5. Securely tape antenna cable to fish tape and pull tape and cable through the selected route.
6. Disconnect fish tape from cable and attach cable to antenna mount.

JOB SHEET #2

7. Apply a thin coat of silicone grease to the antenna mount, and install antenna mount on vehicle.

   (CAUTION: On fiberglass surface or in a hidden location be sure a ground plane is established.)

8. Install antenna on antenna mount.

9. Attach connector to cable.

10. Attach connector to transceiver unit.

11. Check standing-wave ratio (SWR) with vehicle doors and trunk closed.

12. Adjust antenna length if necessary to obtain the correct SWR.

    a. Move antenna up or down in the mount until the correct SWR is obtained.

    b. If antenna is too long, adjust by clipping small lengths of about 1/8 inch from the antenna until the correct SWR is obtained.

    c. If antenna is too short, mount a longer antenna and repeat a and b as necessary to obtain the correct SWR.

13. Dress cable so that it is secure without slack areas being careful to avoid sharp bends and tight coils.

14. Perform final operational check for documented operational parameters.

15. Clean-up residue that may have accumulated during installation and leave unit neat in appearance.

16. Have instructor check your work.

17. Return equipment and materials to their proper storage location.

TWO-WAY COMMUNICATIONS
UNIT XII

JOB SHEET #1 PRACTICAL TEST — INSTALL A TWO-WAY MOBILE RADIO

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Selected proper location for antenna.	______	______
3. Properly installed cable.	______	______
4. Properly installed antenna mount.	______	______
5. Properly connected cable to transceiver.	______	______
6. Obtained satisfactory SWR.	______	______
7. Performed operational check satisfactorily.	______	______
8. Returned tools and materials to proper location.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner. (____hrs. ____min. ____sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Installed in proper location	4	3	2	1
Unit and cables properly connected	4	3	2	1
Installed unit operates correctly	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TWO-WAY COMMUNICATIONS
UNIT XII

JOB SHEET #2 PRACTICAL TEST — INSTALL A TWO-WAY MOBILE ANTENNA

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Selected proper location for antenna.	______	______
3. Properly installed cable.	______	______
4. Properly installed antenna mount.	______	______
5. Properly connected cable to transceiver.	______	______
6. Obtained satisfactory SWR.	______	______
7. Performed operational check satisfactorily.	______	______
8. Returned tools and materials to proper location.	______	______
9. Cleaned the work area.	______	______
10. Used proper tools correctly.	______	______
11. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
12. Practiced safety rules throughout procedure.	______	______
13. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

Installed antenna in proper location	4	3	2	1
Properly routed and installed cable	4	3	2	1
Antenna adjusted for proper SWR	4	3	2	1
Installation is neat and functional	4	3	2	1

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TWO-WAY COMMUNICATIONS
UNIT XII

TEST

NAME ______________________ SCORE ______________________

1. Match the terms on the right with their correct definitions.

_____a. A device that simulates all the electrical characteristics of an antenna except that the energy supplied to it is not radiated

_____b. A device that absorbs energy, thus reducing the power level

_____c. A circuit used in the audio section of an FM receiver to attenuate high frequencies

_____d. A device that couples the receiver and transmitter to a common antenna

_____e. A circuit used in an FM transmitter to amplify the high frequencies

_____f. The ability of a receiver to accept a signal and reflect adjacent signals

_____g. Defines the weakest signal that can be received

_____h. A device that allows the simultaneous transmission of multiple signals in the same channel without interaction

1. Attenuator
2. Combiner
3. De-emphasis circuit
4. Dummy load
5. Duplexer
6. Pre-emphasis circuit
7. Selectivity
8. Sensitivity

2. Match abbreviations related to communication systems on the right with their correct definitions.

(NOTE: Definitions and abbreviations continue on the next page.)

_____a. Single Sideband

_____b. Peak Envelope Power

_____c. Push-To-Talk

1. SINAD
2. PEP
3. SSB

TEST

_____d.	Continuous Tone Coded Squelch System	4. CTCSS
_____e.	Voice Frequency	5. PTT
_____f.	Signal Including Noise And Distortion	6. VF

3. List six two-way radio services.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

4. Complete the following statements concerning types of microphones by circling the word(s) that best complete(s) each statement.

a. (Magnetic, Condenser) microphones operate on a principle of sound waves striking a diaphragm producing a relative movement between a magnetic field and a conductor, inducing a voltage in the conductor.

b. (Crystal, Condenser) microphones convert sound into electrical signals when a diaphragm, mechanically connected to a (capacitor, crystal), is caused to vibrate producing stress on a crystal which in turn produces an AC signal.

c. (Magnetic, Condenser) microphones produce an electrical current through a capacitance that varies in synchronization with sound waves striking a diaphragm.

5. Select true statements related to a basic FM communications system by placing an "X" in the blanks preceding the true statements.

_____a. The purpose of a two-way electronic communications system is to both transmit and receive intelligence via electronic means.

_____b. Either a transmitter or a receiver is present at each operator location.

_____c. When transmitter and receiver are contained within a single package as in a mobile radio, the unit is called a transceiver.

TEST

_____d. The transceiver is in the transmit mode when operating unless the push-to-talk switch on the microphone is depressed.

_____e. The limiter switch activates a transmit-receive (TR) relay which changes the operation from receive to transmit.

_____f. Oscillator is crystal controlled for accuracy and stability of frequency of operation.

_____g. A de-emphasis circuit is used in the transmitter to emphasize the higher audio-frequencies to prevent loss during transmission.

_____h. The frequency tolerance and spectrum for operating units is specified by the FCC.

6. Distinguish between the characteristics of remote relay and repeater stations by placing an "RR" for remove relay in the blank preceding the correct characteristic.

_____a. Transceiver unit which usually operates on a fixed frequency first receiving a signal, amplifying it, and then transmitting the signal on the same frequency.

_____b. Station will receive one frequency and relay its received information to a transmitter which simultaneously radiates the information on another frequency.

7. Select from the following list characteristics of pagers by placing an "X" in the blanks preceding the correct characteristics.

_____a. Safety circuits are built-in

_____b. Shirt, pocket-sized receiver

_____c. Tone activated from base station

_____d. Microprocessor controlled capabilities

_____e. Antenna must be raised to receive

_____f. Voice messages may be given

TEST

8. Complete the following statements concerning transmitter measurements by inserting the word(s) that best complete each statement.

   a. __________ check is made using an NBS frequency counter.

   b. __________ __________ check is made to detect unwanted signals.

   c. Modulation checks are made to determine the __________ of modulation and to detect __________ of modulating signal.

   d. DC power input may be determined by measuring the __________ current drawn by the final stage and multiplying it by the __________ power supply voltage.

   e. RF power output (PEP for SSB) may be determined by using an RF wattmeter to measure __________ being sent to a dummy load.

9. List four types of receiver checks.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

10. Match major test instruments used for checking communication systems on the right with their correct uses.

    (NOTE: Uses and instruments continue on the next page.)

_____a. Used to replace the antenna for testing purposes

_____b. Used to inject standard frequencies

_____c. Used to check VF distortion

_____d. Used to determine standing wave ratio and power output

_____e. Used to check RF output current

1. Frequency counter
2. Communications monitor
3. Distortion analyzer
4. Regulated power supply
5. SINAD meter
6. Dummy load

TEST

_____f. Used to measure sidebands and spurious signals

_____g. Used to check percentage of modulation, and peak envelope power (PEP)

_____h. Used to supply stable power to transmitter

_____i. A type of distortion analyzer consisting of a multi-range AF voltmeter calibrated in dB and a 1000-Hz bandstop filter used to check quieting and sensitivity

_____j. Used to check output frequency of transmitter

_____k. A unit consisting of multiple test instruments capable of analyzing communication systems

7. Calibrated oscilloscope or modulation monitor
8. RF wattmeter/SWR meter
9. Spectrum analyzer
10. Calibrated RF and AF signal generator
11. RF ammeter

11. Complete statements concerning characteristics of trunked and cellular systems by inserting the word(s) that best complete(s) each statement.

a. A ____________ system allows for the sharing of frequency channels by multiple users of the multi-channel system.

b. A trunked system uses a ____________ channel or computers to scan for open channels.

c. A digital burst is used to identify users with an open, but ____________ channel, in modern systems.

d. ____________ systems operate similar to trunked systems in that they switch mobile units between multiple repeaters in a cellular system to maintain the strongest possible signal.

12. Complete statements concerning considerations for interfacing to telephone lines by inserting the word(s) that best complete(s) each statement.

a. Ringing voltages of ____________ volts can cause damage to electronic circuits.

b. Subscriber telephone lines have up to ____________ volts DC across them at all times.

c. Use only approved acoustical ____________ or ____________.

d. Line level of audio should not exceed 0 DBm when read across ____________ ohm telephone lines.

e. "______-______" to lines running in a common cable may be caused by signals greater than 0 DBm.

f. DC control votlages can exceed ____________ volts.

TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Demonstrate the ability to:

    a. Install a two-way mobile radio. (Job Sheet #1)

    b. Install a two-way mobile antenna. (Job Sheet #2)

TWO-WAY COMMUNICATIONS
UNIT XII

ANSWERS TO TEST

1. a. 4
   b. 1
   c. 3
   d. 5
   e. 6
   f. 7
   g. 8
   h. 2

2. a. 3
   b. 2
   c. 5
   d. 4
   e. 6
   f. 1

3. (NOTE: These may be in any order)

   a. Citizens band
   b. Amateur radio
   c. Aeronautical
   d. General mobile radio service
   e. Private land mobile radio service
   f. Domestic landline mobile radio service

4. a. Magnetic
   b. Crystal, crystal
   c. Condenser

5. a, c, f, h

6. a

7. b, c, d, f

8. a. Frequency
   b. Spurious signal
   c. Percent, distortion
   d. Average, average
   e. Power

ANSWERS TO TEST

9. a. Selectivity
   b. Sensitivity
   c. Audio distortion
   d. Squelching threshold

10. a. 6
    b. 10
    c. 3
    d. 8
    e. 11
    f. 9
    g. 7
    h. 4
    i. 5
    j. 1
    k. 2

11. a. Trunked
    b. Control
    c. Private
    d. Cellular

12. a. Ninety (90)
    b. Forty-eight (48)
    c. Couplers, modems
    d. 600
    e. Cross-talk
    f. 260

13. Performance skills evaluated to the satisfaction of the instructor

INTRODUCTION TO MICROWAVE AND SATELLITE SYSTEMS
UNIT XIII

UNIT OBJECTIVE

After completion of this unit, the student should be able to identify components of microwave and satellite systems and describe their functions. Competencies will be demonstrated by completing the assignment sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to microwave and satellite systems with their correct definitions.
2. Match abbreviations related to microwave and satellite systems with their correct descriptions.
3. List five major microwave systems in electronic communications.
4. List three major types of microwave transmission lines.
5. Match devices used for coupling to waveguides with their descriptions.
6. Match major microwave solid state devices with their correct uses.
7. Complete statements concerning major microwave vacuum tubes.
8. List three major types of microwave antennas.
9. Complete statements concerning types of microwave systems.

OBJECTIVE SHEET

10. Express microwave system gain and loss as a mathematical formula.
11. List basic microwave test instruments.
12. Complete statements concerning the characteristics of basic satellite communication systems.
13. Identify local microwave users. (Assignment Sheet #1)
14. Identify satellite locations and programming. (Assignment Sheet #2)

INTRODUCTION TO MICROWAVE AND SATELLITE SYSTEMS
UNIT XIII

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Integrate the following activities throughout the teaching of this unit:

1. Show microwave devices to students.
2. Visit a microwave installation.
3. Invite guest speakers to speak on system maintenance and installation.
4. Identify businesses and agencies in your area who use microwave for communications.
5. Have students align an antenna as a class project.
6. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

H. Give test.

I. Evaluate test.

J. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Lapatine, Sol. *Electronics in Communication*. New York: John Wiley and Sons, 1978.

B. Hardy, James K. *Electronic Communications Technology*. Englewood Cliffs, NJ: Prentice-Hall, 1986.

C. Kennedy, George. *Electronic Communication Systems*. Third Edition. New York: McGraw-Hill Book Company, 1985.

D. Schrader, Robert L. *Electronic Communication*. Fifth Edition. New York: McGraw-Hill Book Company, 1985.

E. Catalog MTV/84. Microwave Filter Company, Inc., 6743 Kinne Street, Syracuse, NY.

INTRODUCTION TO MICROWAVE AND SATELLITE SYSTEMS
UNIT XIII

INFORMATION SHEET

I. **Terms and definitions**

A. Baseband — The composite signal that contains the intelligence and control signals used to modulate the carrier in a microwave or satellite communications system

B. Klystron — Microwave oscillator or amplifier using cavities to modulate an electron stream

C. Magnetron — A microwave oscillator that uses the interaction of magnetic and electric fields in a complex cavity

D. Repeater station — Point in a microwave system where RF carriers are amplified and retransmitted

E. Telemetry — The science and technology of automatic measurement and transmission of data by wire, radio, or other means from remote sources

F. Terminal station — Point in a microwave system where baseband signals are either originated or terminated

G. Waveguide — A transmission line that consists of a suitably shaped hollow conductor and is used to guide ultrahigh and superhigh frequency electromagnetic waves propagated along its length

II. **Abbreviations related to microwave and satellite systems**

A. IMPATT — Impact Avalanche and Transmit Time diode

B. TRAPATT — Trapped Plasma Avalanche Trigger Transit diode

C. LSA — Limited Space-charge Accumulation diode

D. TED — Transferred-Electron Device

(NOTE: This is sometimes called a GUNN diode after the scientist, Professor Gunn, who first demonstrated its operation.)

E. SAW — Surface Acoustic Wave

F. TI — Terrestrial Interference

G. LNA — Low Noise Amplifier

H. TWT — Traveling Wave Tube

I. BWO — Backward Wave Oscillator

INFORMATION SHEET

III. **Major microwave systems in electronic communications**

A. UHF TV

B. Microwave relay

C. Satellite communication

D. Mobile radio

E. Telemetry

IV. **Major types of microwave transmission lines**

A. Coaxial cable

B. Waveguides

C. Strip lines

V. **Devices used for coupling to waveguides**

A. Directional couplers — Transfer of energy through coupling holes from primary to secondary waveguide

B. Inductive loop coupler — Energy transferred by use of a single-loop turn of a coaxial cable conductor connected to the wall of the waveguide

C. Electrostatic probe — Acts as a ¼ wavelength antenna protruding into the waveguide

D. Ferrite isolators — Used as a unidirectional coupler and as a one-way buffer between microwave oscillator and waveguide

VI. **Major microwave solid state devices**

A. Bipolar transistors and FET's — Provide wide bandwidth when used in low-power amplifiers and oscillators

B. Varactor diodes — Used as frequency multipliers

C. IMPATT diode — Used in negative resistance amplifier and oscillator circuits at higher frequencies and higher power levels than bipolar transistors

D. TRAPATT diode — Has high efficiency but limited use as an amplifier and oscillator due to its complex fabrication and associated circuitry

E. TED (GUNN) diodes — Used in negative resistance amplifier and oscillator circuits in the 25 MHz region

(NOTE: These are sometimes called bulk-effect diodes.)

INFORMATION SHEET

F. LSA diodes — Similar to GUNN diodes, but capable of handling higher power levels and frequencies in the 50 GHz region

G. SAW resonator — Used for microwave oscillators and narrowband bandpass filters especially above 50 GHz

VII. **Major microwave vacuum tubes** (Transparencies 1, 2, and 3)

A. Klystron

1. Reflex klystron used for mixer-oscillators

2. Multicavity klystron used for power amplifiers

B. Magnetrons — Used primarily as a pulsed power amplifier in high power radar

C. Traveling wave tube (TWT) — A microwave RF amplifier that uses a helical structure for velocity modulation of an electron beam

D. Backward-wave oscillator (BWO) — Used primarily for microwave RF oscillator circuits

VIII. **Major types of microwave antennas**

A. Parabolic antennas (Transparency 4)

(NOTE: These use the same principles as a parabolic mirror. Directrix is in the imaginary plane from which the output signal rays originate. Aperture plane is the imaginary plane where all the output rays are in phase. Focus (focal point) is the physical as well as the electrical input/output point to the transmitter or receiver.)

B. Horn antennas (Transparency 5)

1. Pyramidal horn

2. Exponentially tapered Pyramidal horn

3. Sectoral H-plane horn

4. Sectoral E-plane horn

5. Pyramidal horn

6. Exponentially tapered conical

7. Conical

8. Biconical

C. Helix antenna

INFORMATION SHEET

IX. **Types of microwave systems**

A. Terminal stations

1. A terminal station has four major sections: the baseband, wire line entrance link, IF section, and RF section.

2. Baseband is the composite signal that modulates the carrier and may comprise one or more of the following:

   a. Frequency-division-multiplexed (FDM) voice band channels

   b. Time-division-multiplexed (TDM) voice band channels

   c. Broadcast-quality composite video or picturephone

3. Wire line entrance link usually consists of an amplifier, an equalizer, and a level-shaping device such as pre-emphasis and de-emphasis networks.

4. The IF section generates a frequency modulated IF carrier in the transmitter and detects the signal in the receiver.

5. The RF section up-converts the IF carrier to the desired RF output frequency and power levels in the transmitter; down-converts in the receiver.

B. Repeater stations

(NOTE: There are basically two types of repeaters: baseband and IF.)

1. An IF repeater receives the RF carrier, down-converts to an IF frequency, amplifies and reshapes the signal, up-converts to RF, and then retransmits.

2. A baseband repeater down-converts, demodulates to the baseband, further demodulates to channel level, reconfigures the signal, modulates, and up-converts IF and to RF carrier, and restransmits.

C. Diversity is employed in systems to increase reliability.

(NOTE: At these frequencies, environmental conditions can rapidly change reliability of a system. Frequency and space diversity are used to counteract the resultant undesirable effects.)

1. Frequency diversity is modulating two different RF carrier frequencies with the same IF intelligence, then transmitting both RF signals with the strongest and best being selected by the receiver.

INFORMATION SHEET

2. Space diversity is accomplished by feeding the transmitter to two or more antennas that are physically separated by an appreciable number of wavelengths.

3. Polarization diversity is accomplished when a single RF carrier is propagated with two different electromagnetic polarizations, vertical and horizontal.

X. **Microwave system gain and loss**

A. System gain is used to predict reliability for given set of system parameters.

B. System gain may be expressed mathematically by the formula:

$$Gs = Pt - Cmin$$

where GS = system gain
Pt = transmitter output power
Cmin = minimum receiver input power of a given quality objective

C. Major system gains are:

1. Transmit antenna gain (dB) relative to an isotrophic radiator

2. Receive antenna gain (dB) relative to an isotrophic radiator

D. Major system losses are:

1. Free-space path loss between antennas

2. Waveguide feeder loss between the distribution network and its respective antenna

3. Total coupling or branching loss in the circulators, filters, and distribution network between the output of a transmitter or the input to a receiver and its respective waveguide feed

4. Fade margin for a given reliability objective

XI. **Microwave test instruments**

A. Signal generators

B. Calorimetric power meters

C. Standing-wave indicators

D. Ratio meters

INFORMATION SHEET

E. Frequency meters and counters

F. Sampling oscilloscopes

G. Spectrum analyzers

H. Function generators

I. X-Y recorders

J. Time domain reflectometer

K. Frequency selective voltmeter (level meter)

L. Frequency meters and counters

XII. **Characteristics of basic satellite communication systems**

A. A satellite system consists of the uplink, satellite transponder, and the downlink.

1. The uplink section consists primarily of the earth station transmitter.

2. The satellite transponder is essentially a radio repeater in the sky which receives the signal from earth, amplifies it, and retransmits it back to earth.

3. The downlink is a highly sensitive earth station receiver.

B. Satellite transmissions are within two categories.

1. The payload transmission is the actual user information that is conveyed throughout the system.

2. Bus transmission includes control mechanisms that support the payload transmissions.

C. Satellites are either orbital or stationary.

1. The orbital or nonsynchronous type orbits the earth in an elliptical or circular pattern with an angular velocity either greater than or less than that of the earth.

2. Geostationary or geosynchronous satellites orbit the earth in a circular pattern with an angular velocity equal to that of the earth.

INFORMATION SHEET

D. Satellites may be classified as passive or active.

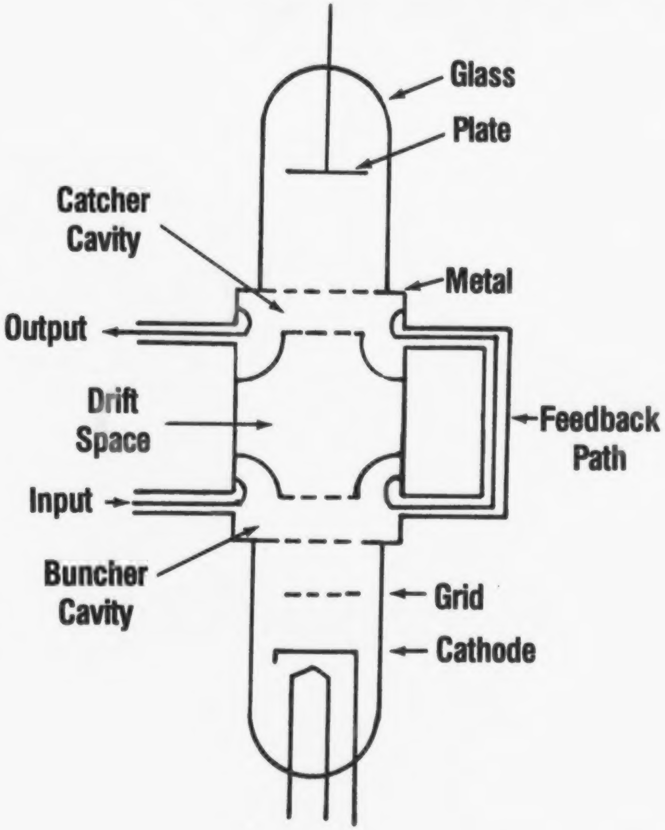
  1. A passive satellite simply reflects a signal back to earth; it contributes losses to the system.

     EXAMPLE: The moon was used by the military as a passive satellite during the late 1940's. It did not amplify the signal but simply acted as a reflector.

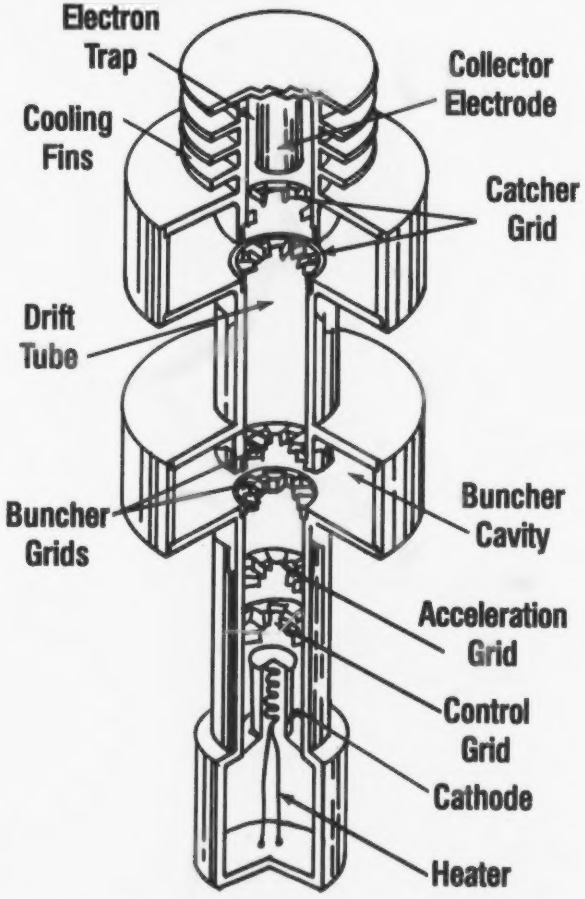
  2. An active satellite is one that electronically repeats a signal back to earth; it contributes to system gain.

E. The elevation angle and azimuth must be known to properly orient an antenna toward a satellite.

Major Microwave Vacuum Tubes

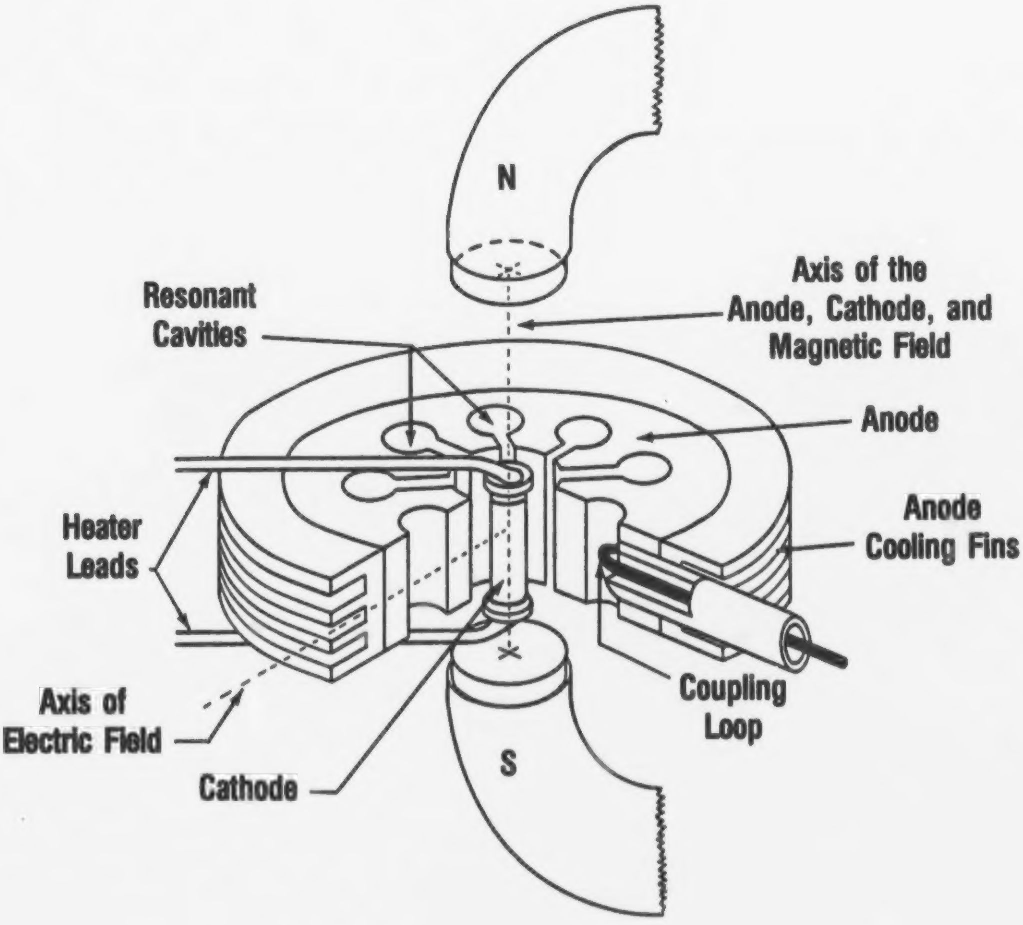

Glass
Plate
Catcher Cavity
Metal
Output
Drift Space
Feedback Path
Input
Buncher Cavity
Grid
Cathode

Klystron Tube with Resonant Cavities


Electron Trap
Collector Electrode
Cooling Fins
Catcher Grid
Drift Tube
Buncher Grids
Buncher Cavity
Acceleration Grid
Control Grid
Cathode
Heater

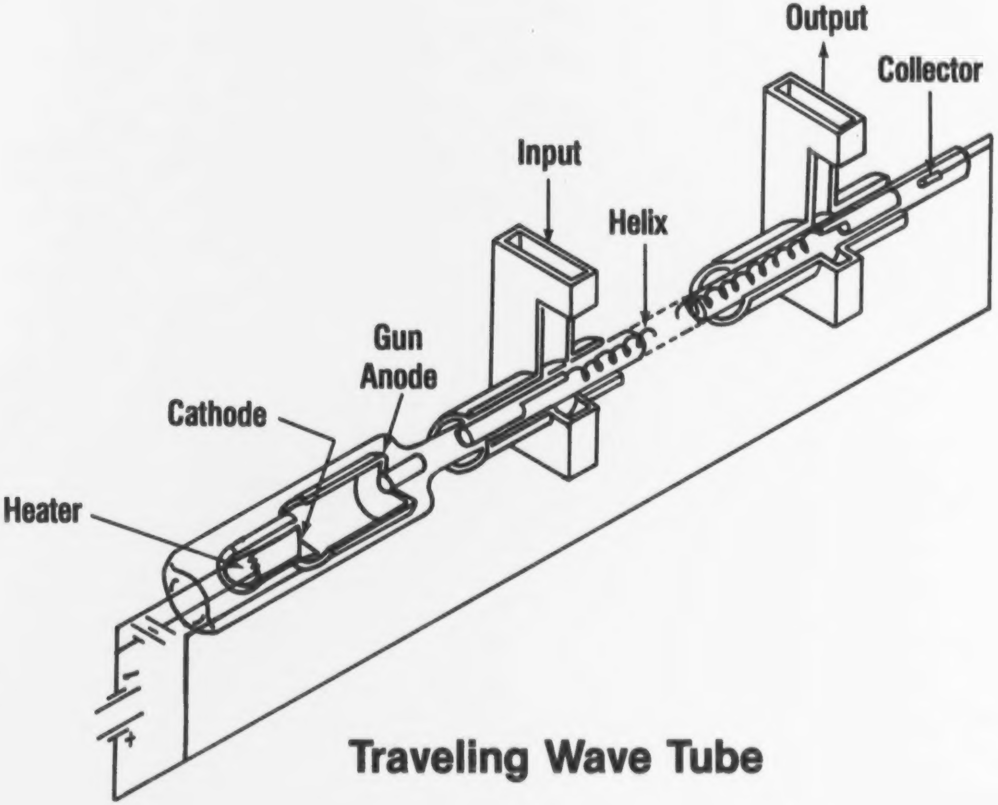
Klystron Internal Structure

Major Microwave Vacuum Tubes (Continued)


N
Resonant Cavities
Axis of the Anode, Cathode, and Magnetic Field
Anode
Anode Cooling Fins
Heater Leads
Coupling Loop
Axis of Electric Field
Cathode
S

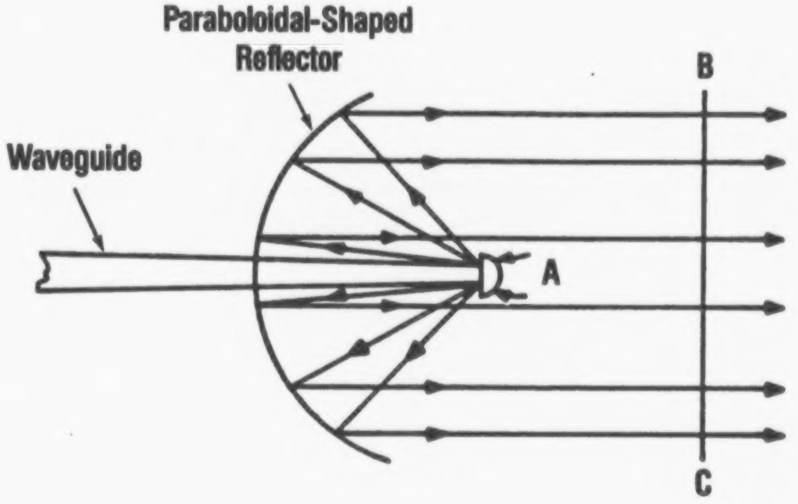
Magnetron

Major Microwave Vacuum Tubes (Continued)


Output
Collector
Input
Helix
Gun Anode
Cathode
Heater
+

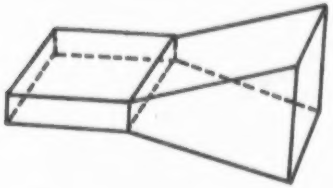
Traveling Wave Tube

Major Types of Microwave Antennas

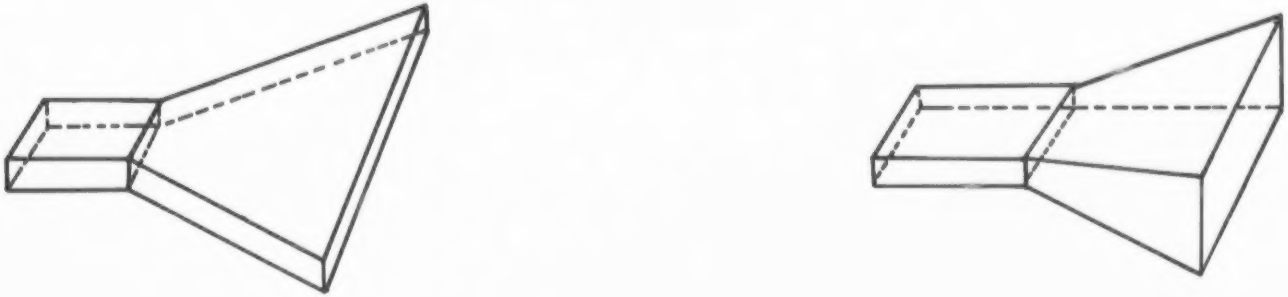

Paraboloidal-Shaped Reflector
Waveguide
A
B
C

Parabolic Antenna

Major Types of Microwave Antennas (Continued)



"E" Plane Sectoral Horn



"H" Plane Sectoral Horn

Pyramid Horn

Horn Antennas

INTRODUCTION TO MICROWAVE AND SATELLITE SYSTEMS
UNIT XIII

ASSIGNMENT SHEET #1 — IDENTIFY LOCAL MICROWAVE USERS

NAME ______________________________ SCORE ______________

1. With information you now know and have available, identify a list of at least five possible users or microwave systems. Give the name of the company or agency, address, and phone number.

Company/Agency Name	Address	Phone No.

2. Using the list of users above, verify their usage and for what purpose(s) the microwave system is used in the company/agency. You may complete this step by using published information, by making appointments for a personal interview with a company representative, or by verifying their usage with a phone call to the public relations representative of the company.

Company name ______________________________

Identified uses of microwave ______________________________

____

Company name ______________________________

Identified uses of microwave ______________________________

____

Company name ______________________________

Identified uses of microwave ______________________________

____

ASSIGNMENT SHEET #1

Company name ______________________________

Identified uses of microwave ______________________

____

Company name ______________________________

Identified uses of microwave ______________________

____

INTRODUCTION TO MICROWAVE AND SATELLITE SYSTEMS
UNIT XIII

ASSIGNMENT SHEET #2 — IDENTIFY SATELLITE LOCATIONS AND PROGRAMMING

NAME ____________________ SCORE ____________

Directions: Obtain a satellite programming schedule and identify five satellites from which programming is commonly viewed by the population in your area. Satellite locations and their respective programming are available through numerous sources including Satellite TV Week, P.o. Box 308, Fortuna, CA, 95540-0308, and Onsat, 501 N. Washington St., Shelby, NC, 28150.

1. List the name of five satellites, their geographic locations (azimuth & elevation) with respect to your school, and the frequency band (i.e., KU, C, etc.) on which they operate.

Satellite	Azimuth	Elevation	Band

2. Identify three TV channels which you watch locally. Determine the network which provides the programming on each, then identify the satellite which broadcasts the programming for that network.

Channel	Network	Satellite

INTRODUCTION TO MICROWAVE AND SATELLITE SYSTEMS
UNIT XIII

TEST

NAME ________________________ SCORE ________________________

1. Match the terms on the right with their correct definitions.

_____a. The composite signal that contains the intelligence and control signals used to modulate the carrier in a microwave or satellite communications system

_____b. Point in a microwave system where baseband signals are either originated or terminated

_____c. Point in a microwave system where RF carriers are amplified and retransmitted

_____d. A transmission line that consists of a suitably shaped hollow conductor and is used to guide ultrahigh and superhigh frequency electromagnetic waves propagated along its length

_____e. The science and technology of automatic measurement and transmission of data by wire, radio, or other means from remote sources

_____f. Microwave oscillator or amplifier using cavities to modulate an electron stream

_____g. A microwave oscillator that uses the interaction of magnetic and electric fields in a complex cavity

1. Baseband
2. Klystron
3. Magnetron
4. Repeater station
5. Telemetry
6. Terminal station
7. Waveguide

TEST

2. Match the abbreviations related to microwave and satellite systems on the right with their correct descriptions.

_____a. Impact Avalanche and Transmit Time Diode

_____b. Trapped Plasma Avalanche Trigger Transmit Diode

_____c. Limited Space-charge Accumulation Diode

_____d. Transferred-Electron Device

_____e. Surface Acoustic Wave

_____f. Terrestrial Interference

_____g. Low Noise Amplifier

_____h. Traveling Wave Tube

_____i. Backward Wave Oscillator

1. TED
2. BWO
3. TRAPATT
4. IMPATT
5. TWT
6. LNA
7. TI
8. LSA
9. SAW

3. List five major microwave systems in electronic communications.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

4. List three major types of microwave transmission lines.

a. ______________________________

b. ______________________________

c. ______________________________

TEST

5. Match devices used for coupling to waveguides on the right with their descriptions.

_____a. Acts as a ¼ wavelength antenna protruding into the waveguide

_____b. Used as a unidirectional coupler and as a one way buffer between microwave oscillator and waveguide

_____c. Energy transferred by use of a single-loop turn of a coaxial cable conductor connected to the wall of the waveguide

_____d. Transfer of energy through coupling holes from primary to secondary waveguide

1. Directional couplers
2. Inductive loop coupler
3. Electrostatic probe
4. Ferrite isolators

6. Match major microwave solid state devices on the right with their correct uses.

_____a. Used in negative resistance amplifier and oscillator circuits at higher frequencies and higher power levels than bipolar transistors

_____b. Similar to GUNN diodes, but capable of handling higher power levels and frequencies in the 50 GHz region

_____c. Used in negative resistance amplifier and oscillator circuits in the 25 MHz region

_____d. Has high efficiency but limited use as an amplifier and oscillator due to its complex fabrication and associated circuitry

_____e. Used as frequency multipliers

_____f. Used for microwave oscillators and narrowband bandpass filters especially above 50 GHz

_____g. Provide wide bandwidth when used in low-power amplifiers and oscillators

1. Bipolar transistors and FET's
2. Varactor diodes
3. IMPATT diode
4. TRAPATT diode
5. TED (GUNN) diode
6. LSA diode
7. SAW resonator

TEST

7. Complete the following statements concerning major microwave vacuum tubes by circling the word(s) that best complete(s) each statement.

   a. (Multicavity, Reflex) klystron is used for mixer-oscillators.

   b. (Magnetron, Traveling wavetube) is used primarily as a pulsed power amplifier in high power radar.

   c. (Reflex klystron, backward-wave oscillator) is used primarily for microwave RF oscillator circuits.

   d. (Backward-wave oscillator, Traveling wave tube) is a microwave RF amplifier that uses a helical structure for velocity modulation of an electron beam.

8. List three major types of microwave antennas.

   a. ______________________________

   b. ______________________________

   c. ______________________________

9. Complete the following statements concerning a basic microwave system by inserting the word(s) that best complete(s) each statement.

   a. A ____________ station has four major sections: the baseband, wire line entrance link, IF section, and RF section.

   b. ____________ is the composite signal that modulates the carrier.

   c. There are basically two types of repeaters: ____________ and ____________ .

   d. Diversity is employed in systems to increase ____________ .

   e. ____________ diversity is the modulating of two different RF carrier frequencies with the same IF intelligence, then transmitting both RF signals with the strongest and best being selected by the receiver.

   f. ____________ diversity is accomplished by feeding the transmitter to two or more antennas that are physically separated by an appreciable number of wavelengths.

   g. ____________ diversity is accomplished when a single RF carrier is propagated with two different electromagnetic polarizations, vertical and horizontal.

TEST

10. Express microwave system gain and loss as a mathematical formula.

____

11. List eight basic microwave test instruments below.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

12. Complete the following statements concerning the characteristics of basic satellite communication systems by inserting the word(s) that best complete(s) each statement.

a. A satellite system consists of the __________, satellite __________, and the __________.

b. The __________ section of a satellite system consists primarily of the earth station transmitter.

c. The satellite __________ is essentially a radio repeater in the sky which receives the signal from earth, amplifies it, and retransmits it back to earth.

d. The __________ of a satellite system is a highly sensitive earth station receiver.

e. Satellites are either __________ or __________.

f. The __________ or nonsynchronous type of satellite orbits the earth in an elliptical or circular pattern with an angular velocity either greater than or less than that of the earth.

g. __________ or geosynchronous satellites orbit the earth in a circular pattern with an angular velocity equal to that of the earth.

TEST

h. A _____________ satellite simply reflects a signal back to earth; it contributes losses to the system.

i. An _____________ satellite is one that electronically repeats a signal back to earth; it contributes to system gain.

j. _____________ angle and _____________ must be known to properly orient an antenna toward a satellite.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Identify local microwave users. (Assignment Sheet #1)

14. Identify satellite locations and programming. (Assignment Sheet #2)

INTRODUCTION TO MICROWAVE AND SATELLITE SYSTEMS
UNIT XIII

ANSWERS TO TEST

1. a. 1
   b. 6
   c. 8
   d. 7
   e. 5
   f. 2
   g. 3

2. a. 4
   b. 3
   c. 8
   d. 1
   e. 9
   f. 7
   g. 6
   h. 5
   i. 2

3. a. UHF TV
   b. Microwave relay
   c. Mobile radio
   d. Telemetry
   e. Satellite communications

4. a. Coaxial cable
   b. Waveguides
   c. Strip lines

5. a. 3
   b. 4
   c. 2
   d. 1

6. a. 3
   b. 6
   c. 5
   d. 4
   e. 2
   f. 7
   g. 1

7. a. Reflex
   b. Magnetron
   c. Backward-wave oscillator
   d. Traveling wave tube

8. a. Parabolic
   b. Horn
   c. Helix

ANSWERS TO TEST

9. a. Terminal
   b. Baseband
   c. Baseband, IF
   d. Reliability
   e. Frequency
   f. Space
   g. Polarization

10. Gs = Pt − Cmin

11. Any eight of the following:

    a. Signal generator
    b. Caloric power meter
    c. Standing wave indicator
    d. Ratio meters
    e. Frequency meter and counter
    f. Sampling oscilloscope
    g. Spectrum analyzer
    h. Function generator
    i. X-Y recorders
    j. Time-domain reflectometer
    k. Frequency selective voltmeter (level meter)
    l. Frequency meters and counters

12. a. Uplink, transponder, downlink
    b. Uplink
    c. Transponder
    d. Downlink
    e. Orbital, stationary
    f. Orbital
    g. Geostationary
    h. Passive
    i. Active
    j. Elevation, azimuth

13.-14. Evaluated to the satisfaction of the instructor

OPTICAL COMMUNICATIONS DEVICES AND SYSTEMS

UNIT XIV

UNIT OBJECTIVE

After completion of this unit, the student should be able to construct and analyze optical communications equipment such as sources, detectors, couplers, connectors, and splices. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to optical communications devices and systems with their correct definitions.
2. Match abbreviations related to optical communications devices and systems with their correct definitions.
3. Match stages of a TX/RX optical communication system with their correct descriptions.
4. Match types of optical communications with their correct uses.
5. Complete statements concerning the advantages of optical communications.
6. Identify the parts of a fiber-optic cable.
7. Complete statements concerning characteristics of light transmission through optical fibers.
8. Match types of optical cables with their correct performance.

OBJECTIVE SHEET

9. Complete statements concerning characteristics of optical fiber.

10. Distinguish between loss factors of optical cables.

11. List four types of connectors used with fiber-optic cable.

12. List five requirements of optical connectors.

13. List three types of splices used with fiber-optic cable.

14. Complete statements concerning the basic coupler operation.

15. Identify couplers used in fiber optics.

16. List four areas of optical cable installation.

17. Demonstrate the ability to:

    a. Use the multimeter to check optical diodes. (Job Sheet #1)

    b. Construct and analyze a detector circuit. (Job Sheet #2)

OPTICAL COMMUNICATIONS DEVICES AND SYSTEMS
UNIT XIV

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

  1. Show the students examples of various types of optical cable.
  2. Show the students connectors, splices, and couplers used with optical fibers.
  3. Invite representatives from industry to talk to the class about optical systems.
  4. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN DEVELOPING THIS UNIT

A. Sherman, Ken. *Data Communications, A User's Guide*. Second Edition. Reston, VA: Reston Publishing Company, 1985.

B. Hughes, Fredrick W. *Basic Electronics, Theory, and Experimentation*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1984.

C. *Optoelectronics Selector Guide and Cross Reference*. Motorola Semiconductor Products, Inc., 1984.

OPTICAL COMMUNICATIONS DEVICES AND SYSTEMS
UNIT XIV

INFORMATION SHEET

I. **Terms and definitions**

A. Attenuation — A loss of signal amplitude during transmission

B. Beamsplitter — A light splitting device using a plate coated with a partially reflective material where a portion of the light transmits through the plate and a portion is reflected

C. Characteristics — Inherent and measurable properties that will vary the ability of something

D. Cladding — The layer that surrounds the fiber core and contains a lower index of refraction

E. Connector — A device used to connect or disconnect optical devices such as the source, detector, or fibers

F. Coupler — A device that divides or combines light signals as required

G. Critical angle — Where the refracted signal is 90° from the normal

H. Dispersion — A phenomena that causes broadening or spreading of light as it propagates through an optical fiber

I. Fiber-optics — A method of carrying information from one point to another using a thin strand of glass or plastic which carries light instead of electricity

J. Fiberscope — A glass rod utilized in medicine to look inside the body

K. Graded-index fiber — Fiber that consists of various layers of fiber, similar to the rings of a tree trunk

L. Index of refraction — A ratio of the velocity of light in free space to the velocity of light of a specific material

M. Jacket — The outer sheath that insulates and protects cabling against the environment

N. Modal dispersion — Dispersion resulting from different transit lengths of various propagating modes causing the various signals to exit at different times

O. Mode — The path that light will follow when transmitted through an optical fiber

INFORMATION SHEET

P. Normal line — An imaginary line perpendicular to the connecting line between the core material and the cladding material

Q. Refraction - In optical fiber this is the deflection of light

R. Speed of light — The velocity of electromagnetic energy in a vacuum (186,000 mi/sec)

S. Splice — A device used to make permanent connections between different fibers

T. Tensile strength — The ability of a fiber to be stretched or pulled without breaking

U. Wavelength — The distance a sine wave travels in a cycle ($\lambda = v/f$)

II. **Abbreviations related to optical communications devices and systems**

A. WDM — Wavelength division multiplexing

B. PCM — Pulse coded modulation

C. TX — Transmitter

D. RX — Receiver

E. THz — Terahertz (1,000,000,000,000 HZ)

F. Hz — Hertz

G. λ — Wavelength

H. V — Velocity of the sine wave

I. f — Frequency

J. PCS — Plastic-clad silica (glass)

K. NA — Numerical aperature

L. LASER — Light amplification of simulated emission of radiation

M. DNP — Dry, no polish

N. Ω — Ohms

INFORMATION SHEET

III. Stages of a TX/RX optical communication system (Transparency 1)

A. Driver — Receives the signal from the user equipment and converts the signal to a modulation code

B. Source (electrooptic transducer) — Consists of either an LED or a laser diode which transmits light pulses in comparison to the modulated signal received from the driver

C. Optical cable — A thin cable of glass or plastic used to transmit light signals from one point to another

D. Detector (optoelectric transducer) — A photodiode used to convert the light pulses transmitted by the source back into a modulated signal at the receiver

E. Amplifier — Amplifies the receiver signal from the detector and sends this signal to the user equipment

IV. Types of optic communications

A. Lanterns — Used by the Bostonians for Paul Revere's ride

B. Lamps — Used by navy signalmen and lighthouses

C. Optical telegraph — A communication system that connected Boston and Martha's Vineyard

D. Internal reflections — Light signals traveling through a stream of water, even going around corners

E. Photophone — A series of lenses and mirrors creating light modulation due to the voice vibrating the mirror

F. Glass rods — Glass rods carrying images such as the fiberscope

G. Laser — A device that amplifies light waves and concentrates them in a narrow, very intense beam

H. Fiber optics — A process of sending signals through glass for long distances, used widely in communications

V. Advantages of optical communications

A. Information carrying ability increases with increased bandwidth.

B. Information carrying ability increases with increased carrier frequency which for fiber optics is about 100 THZ.

INFORMATION SHEET

C. Power loss of attenuation in coaxial cable increases with frequency where optical cable loss remains steady with frequency increases.

D. Losses require additional repeaters in the transmission line; since fiber optics have less loss, fewer repeaters are required.

E. Fiber-optic cable is immune to electromagnetic radiation so fiber optics can be run beside other cables with no interference.

F. Fiber-optic cable does not radiate energy, thus making it virtually impossible to tap without detection.

G. A fiber-optic cable is smaller than a copper cable, thus allowing several fiber-optic cables to be run in the same space as one copper cable.

(NOTE: A copper cable 4.5 inches in diameter can carry approximately 40,000 two-way communications where a fiber optic cable 0.5 inches in diameter can carry approximately 1,750,000 two-way communications.)

H. For the same transmission requirements the weight of fiber-optic cable would be approximately 9 lbs/1000 ft. where copper would be approximately 80 lbs/1000 ft.

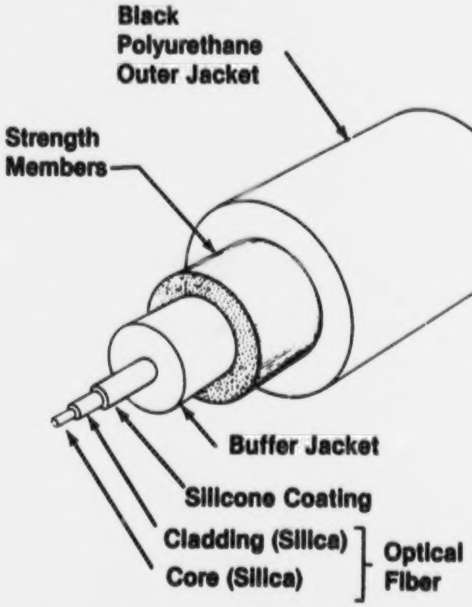
I. Fiber optics transmit only light, thus there is no electrical shock, no sparks for fire, and they can be run safely through fuel tanks or other hazardous areas.

(NOTE: Industry is presently putting fiber optics in existing oil pipe lines.)

J. Fiber optics are cheaper due to less cables being necessary, they are lighter in weight, need fewer repeaters, and carry more signals with less interference than standard cables.

INFORMATION SHEET

VI. Parts of a fiber-optic cable


Black Polyurethane Outer Jacket
Strength Members
Buffer Jacket
Silicone Coating
Cladding (Silica)
Core (Silica)
Optical Fiber

Reprinted with permission from Hewlett-Packard.

VII. Characteristics of light transmission through optical fiber (Transparencies 2 and 3)

A. Light passing from a low refractive index (n2) to a higher one (n1) causes the angle of refraction to decrease or is bent toward the normal.

B. Light passing from a higher refractive index (n1) to a lower one (n2) causes the angle of refraction to increase or is bent away from the normal or toward the critical angle.

C. When the angle of incidence causes the angle of refraction to increase above the critical angle, reflection occurs.

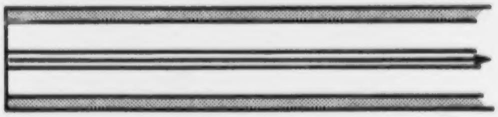
D. The higher the differences of indices, the greater amount of the light will be reflected.

INFORMATION SHEET

VIII. Types of optical cable and their performance

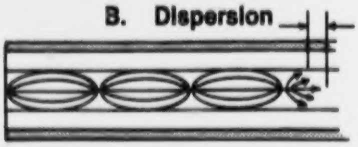
(NOTE: The following optical cable is listed in order of performance from the highest to the lowest.)

A. Single mode — By using only one mode, modal dispersion does not exist and the signal will be more efficient



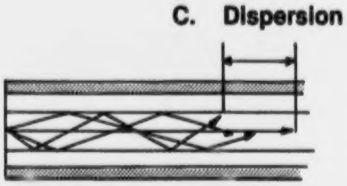
AMP Incorporated.

B. Graded index — By using graded index fiber with each ring outward having a lower index of refraction, the modes do not interact (Transparency 2)



AMP Incorporated.

C. Step index glass — The use of glass PCS and plastic fiber in one cable causes light signals to use different paths causing modal dispersion



AMP Incorporated.

D. PCS — Consists of a glass core with a plastic cladding

E. Plastic — Constructed of a plastic core and plastic cladding

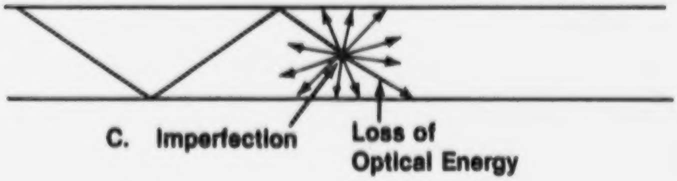
INFORMATION SHEET

IX. **Characteristics of optical fiber**

A. Dispersion may be modal, material, or waveguide.

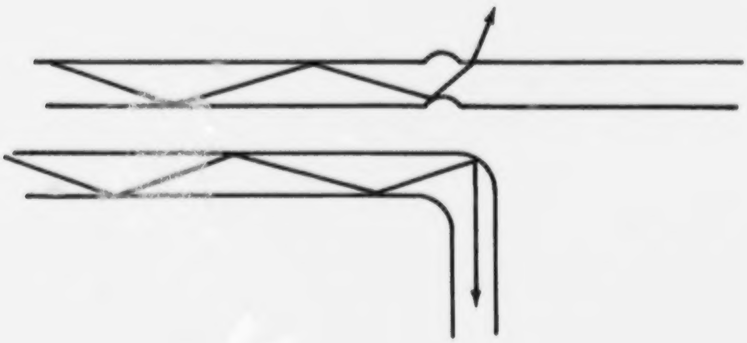
B. Attenuation is a loss of signal power as light travels through a fiber optic cable.

C. Scattering is a loss of energy due to imperfections in the fiber cable.



D. Absorption is a loss in power caused by impurities in the fiber converting optical power into heat.

E. Microbend loss is caused by bumps in the core-to-cladding interface creating angles that will not allow the light to reflect, or cables with too sharp a bend radius.



F. Numerical aperature is the light gathering ability of the fiber or light injected into the fiber at angles greater than the critical angle.

INFORMATION SHEET

G. The tensile strength of a fiber is greater than that of metal cable, but microscopic cracks and flaws of fiber cause fiber weakness.

H. The bend radius of fiber glass cable must be five times the cable diameter for unstressed cable and ten times the diameter for stressed cable or the fiber will snap.

I. Optical fibers are unaffected by nuclear blasts except for an increase in attenuation when subjected to high levels of continuous radiation, but within seconds after the radiation clears fiber, cables are operational.

X. **Loss factors of optical cables**

A. Internal factors (Transparency 4)

1. NA mismatch
2. Core diameter mismatch
3. Concentricity
4. Ellipticity
5. Cladding diameter mismatch

B. External factors (Transparency 5)

1. Lateral displacement
2. End separation
3. Angular misalignment
4. Surface finish should be smooth

XI. **Types of connectors**

(NOTE: Below are some of the various connectors for fiber optics that are in use at this time.

A. Ribbon cable array connector (Transparency 6)

B. SMA connectors (Transparency 7)

C. Plastic-ferrule simplex connector (Transparency 7)

D. DNP connector (Transparency 7)

INFORMATION SHEET

XII. **Ideal requirements of optical connectors**

- A. Low power loss
- B. Easy installation
- C. Connect/disconnect repeatability
- D. Loss consistency
- E. Economical

XIII. **Types of splices**

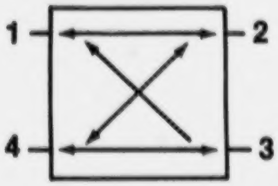
- A. Fusion splice

  (NOTE: This is the most perfect splice but also very expensive.)

- B. Elastomeric splice (Transparency 8)
- C. Four-rod splice (Transparency 9)

XIV. **Basic coupler operation**

(NOTE: The coupler shown below is an example of a four-part directional coupler.)



- A. The arrows indicate the possible directions of signal flow through the coupler.
- B. Light injected into parts one or four will only appear through parts two and three.
- C. Light injected into parts two and three will only appear through parts one and four.
- D. The coupler is a bidirectional device.
- E. The part across from the input is the throughpart, while the other part is the top part.
- F. The throughpart is the greater power output.

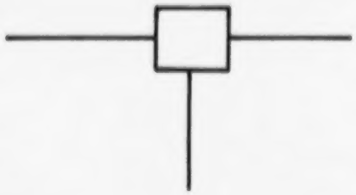
INFORMATION SHEET

XV. **Types of couplers**

(NOTE: The couplers below are only a few of the many types of couplers in existence, but the operational theory is much the same.)

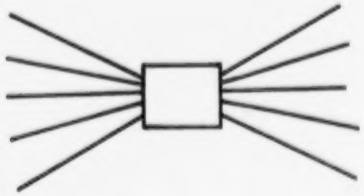
A. Tee connector

(NOTE: Losses increase linearly with the number of terminals.)



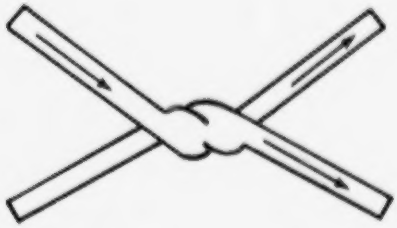
B. Star connector

(NOTE: Losses do not increase linearly, thus making them more useful for a large number of connections.)



C. Fused couplers

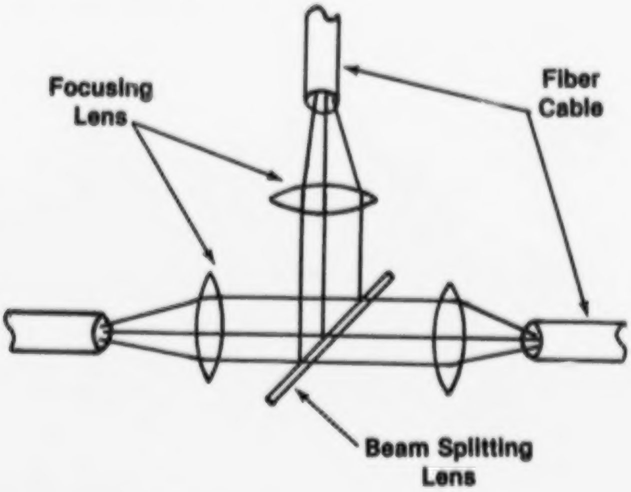
(NOTE: The fibers are fused together allowing light to go into any fiber on the other side.)



INFORMATION SHEET

D. Beamsplitter

(NOTE: The collimating and focusing lens control the coupling and reduce losses in the coupler.)



XVI. Areas of optical cable installation

(NOTE: Optical cable can be installed almost anywhere other types of cable can be installed.)

A. Direct burial installation

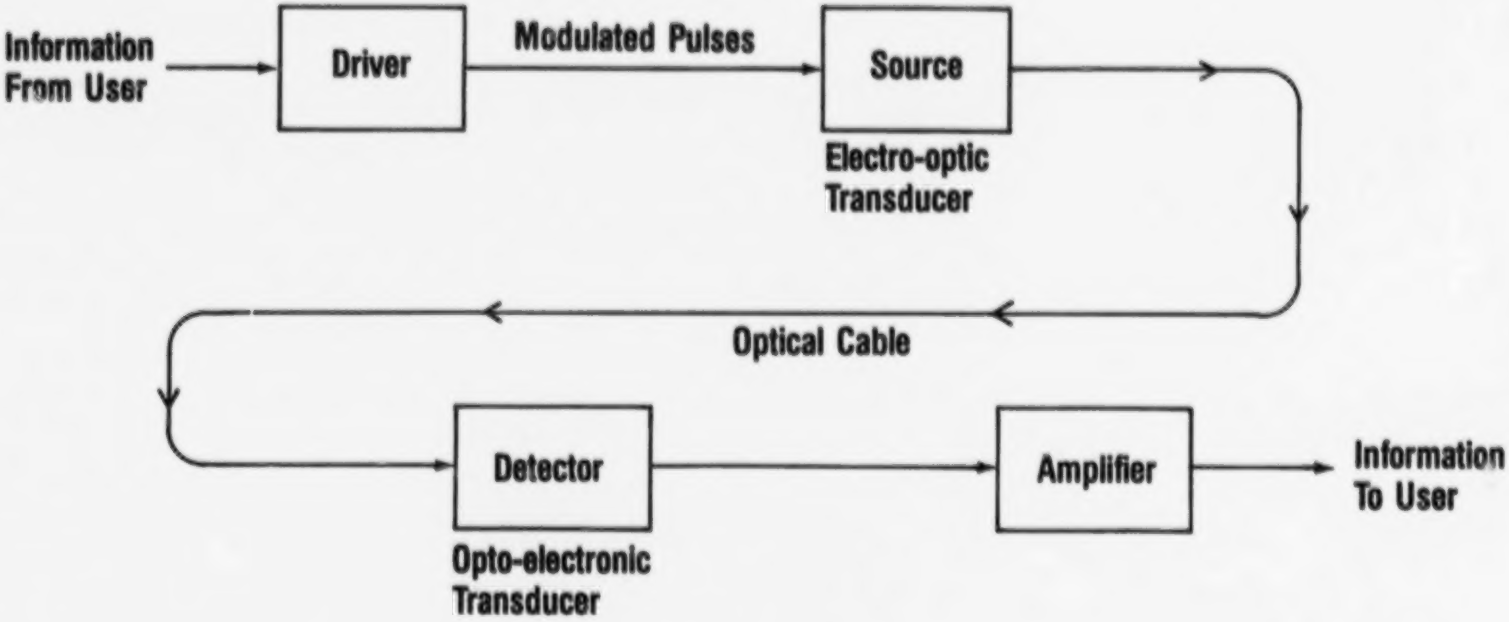
B. Aerial installation

C. Conduit

D. Cable trays

(CAUTION: Care should be given with optical cable during installation due to the possibility of snapping glass cable.)

Optical Communications System



Information From User

Driver

Modulated Pulses

Source

Electro-optic Transducer

Optical Cable

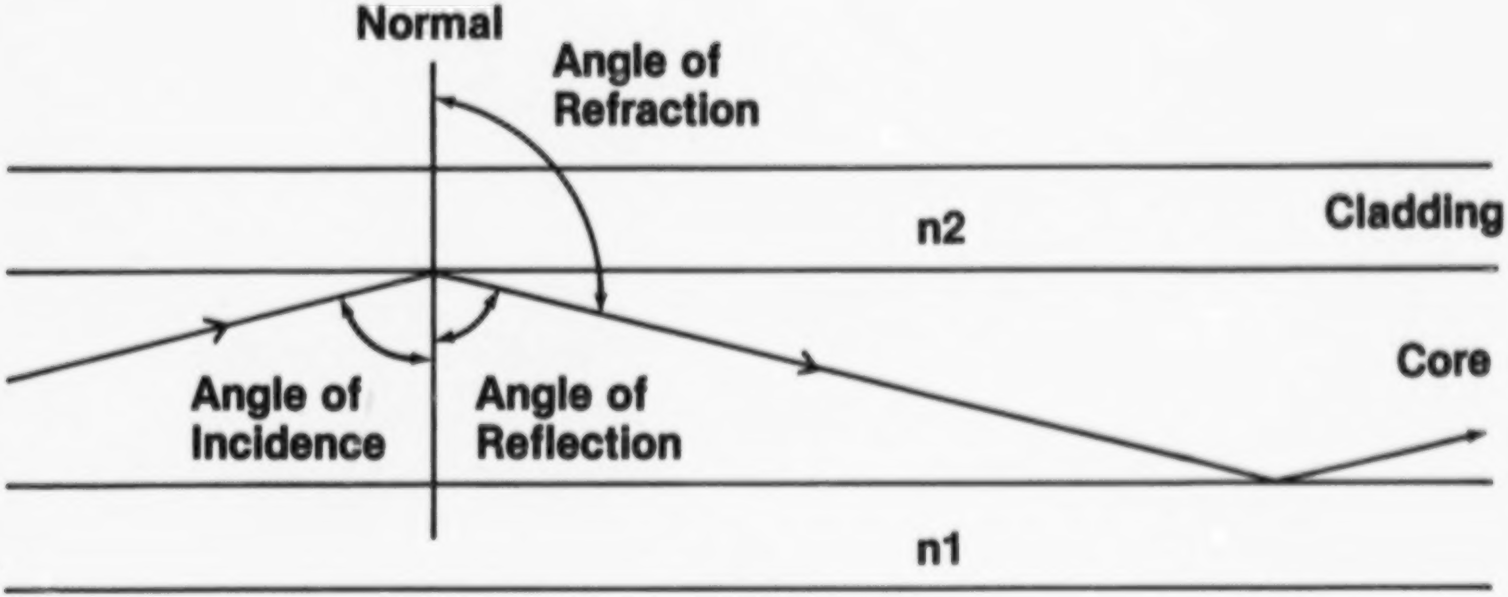
Detector

Opto-electronic Transducer

Amplifier

Information To User

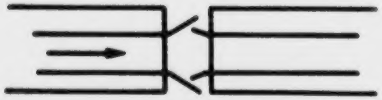
Optical Fiber Light TX


Normal
Angle of Refraction
Cladding
n2
Core
Angle of Incidence
Angle of Reflection
n1

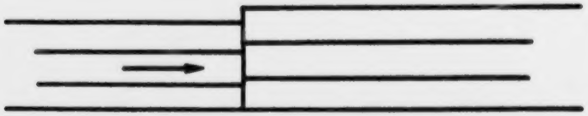
Refraction Indices

MATERIAL	INDEX (n)	LIGHT VELOCITY (km/s)
Vacuum	1.0	300,000
Air	1.0003 (1)	300,000
Water	1.33	225,000
Fused quarts	1.46	205,000
Glass	1.5	200,000
Diamond	2.0	150,000
Silicon	3.4	88,000
Gallium arsenide	3.6	83,000

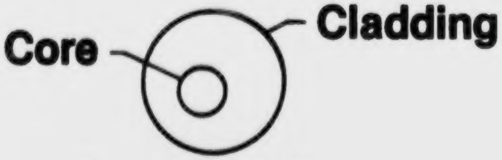
Loss Factors of Connectors



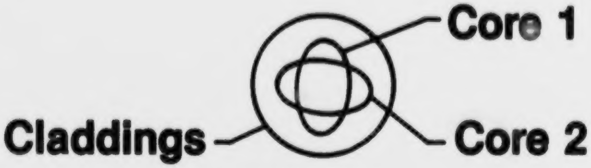
NA Mismatch



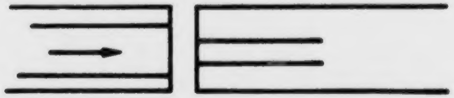
Cladding Diameter Mismatch


Core
Cladding

Concentricity

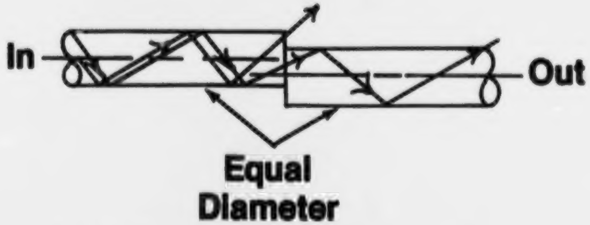

Core 1
Claddings
Core 2

Ellipticity (Ovality)

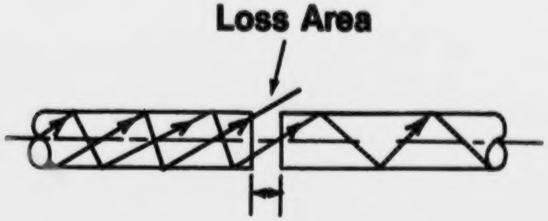


Core Diameter Mismatch

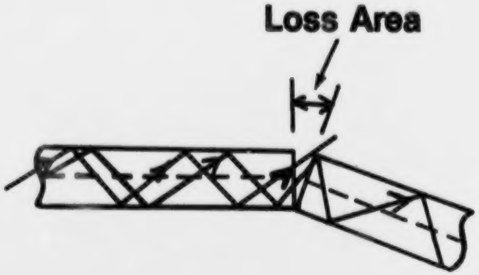
Loss Factors of Connectors (Continued)


In
Out
Equal
Diameter

Lateral Displacement

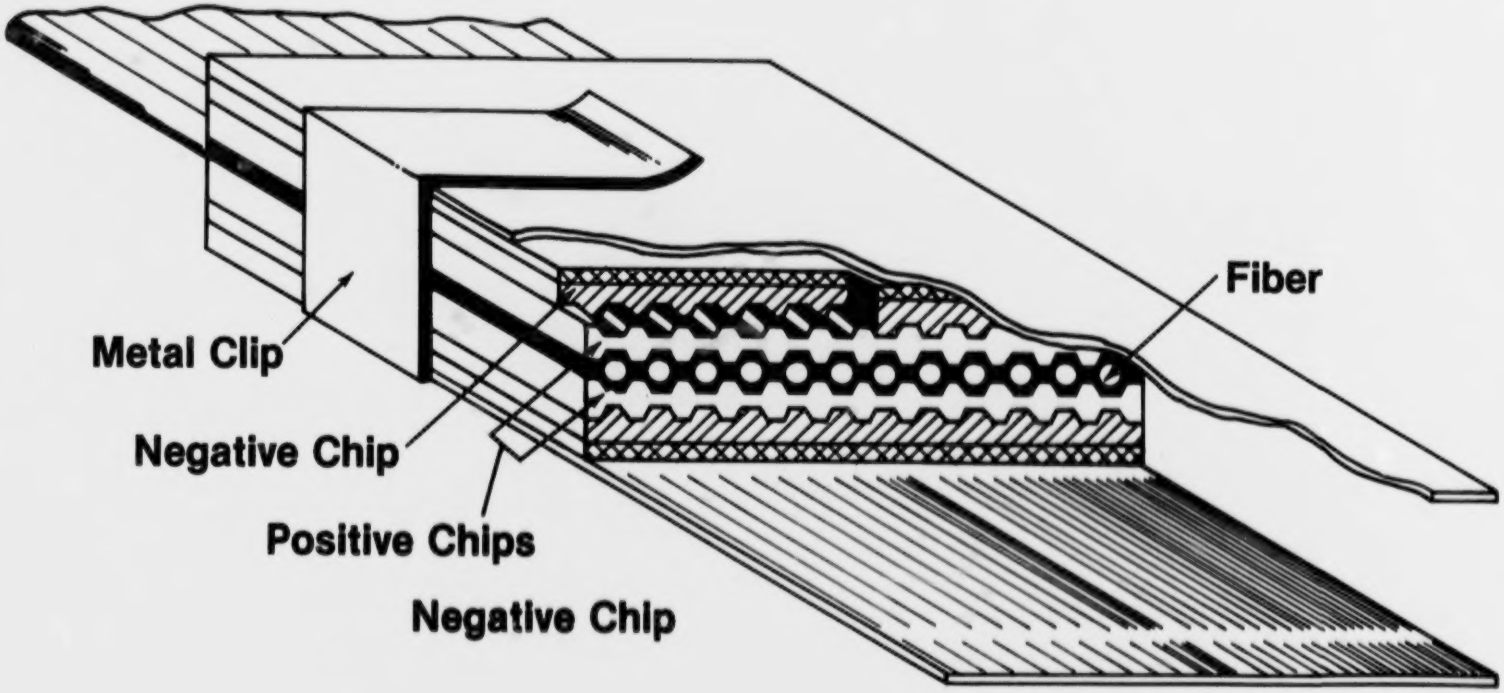


End/Gap Displacement



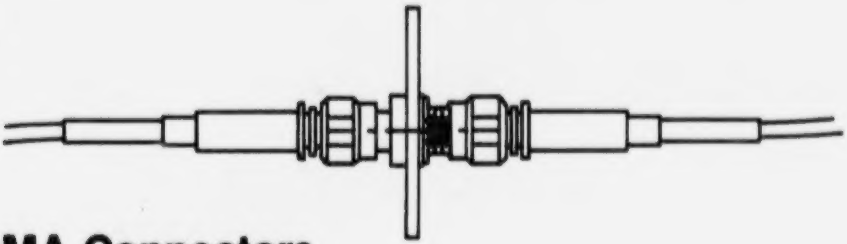
Angular Misalignment

Ribbon Cable Array Connector

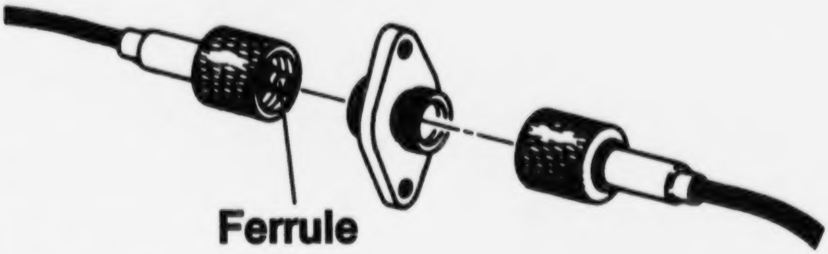

Fiber
Metal Clip
Negative Chip
Positive Chips
Negative Chip

Courtesy of AT&T Bell Laboratories.

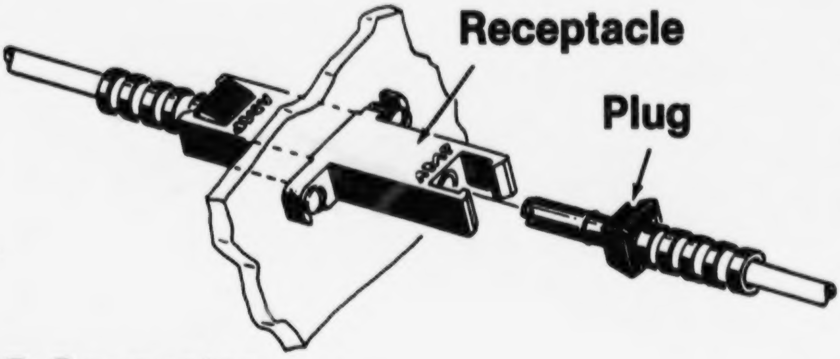
Types of Connectors



SMA Connectors



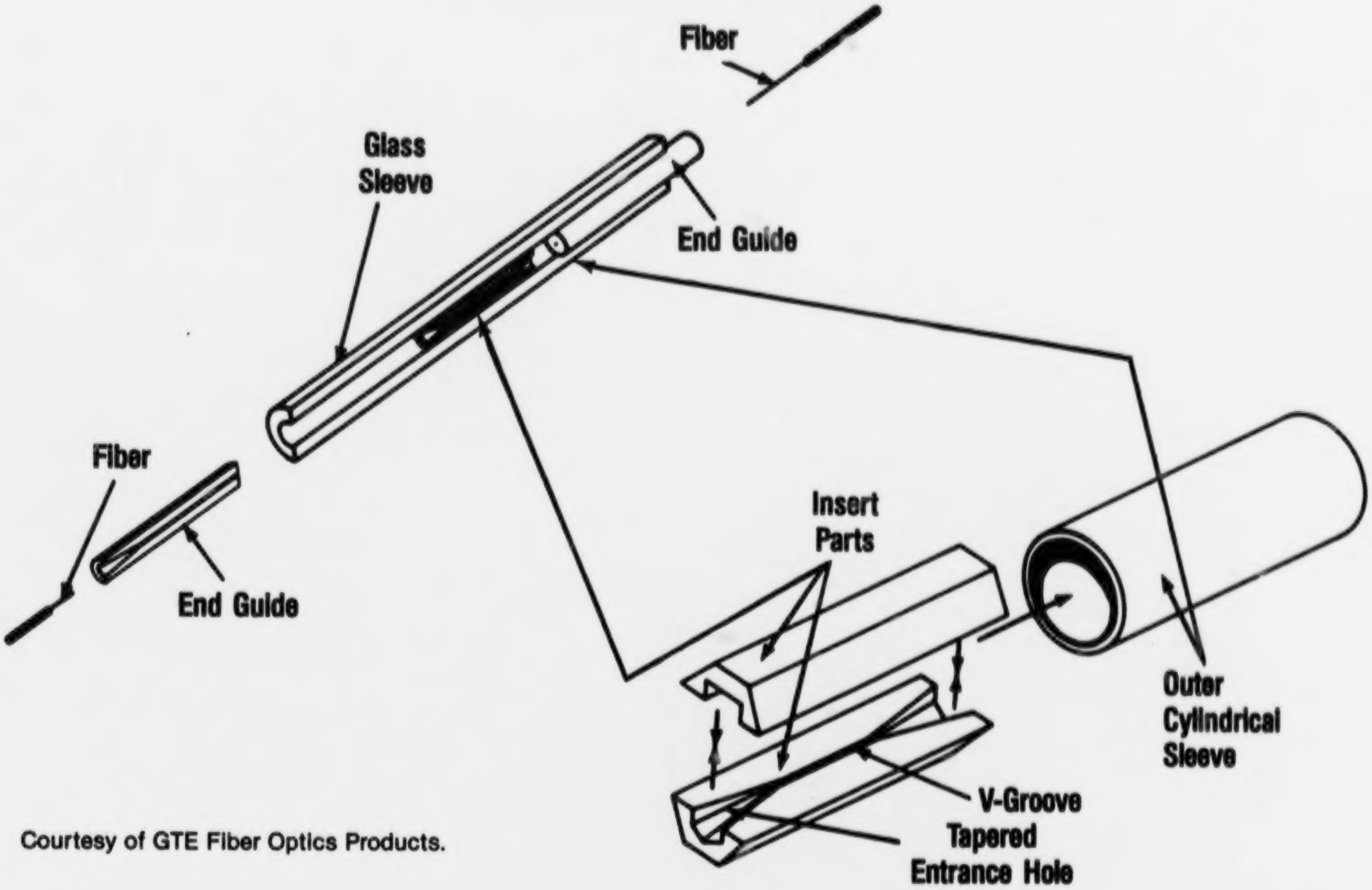
Plastic-Ferrule Simplex Connector


Receptacle
Plug

DNP Connector

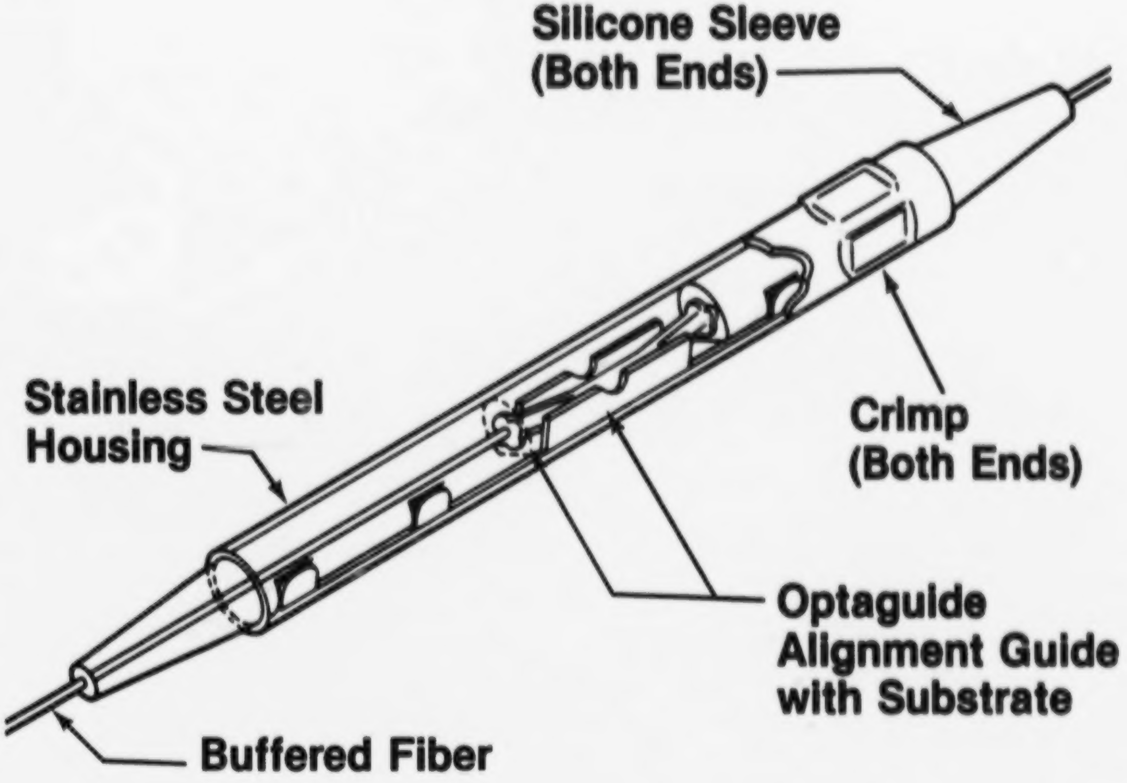
Courtesy of AMP Incorporated.

Elastomeric Splice


Fiber
Glass Sleeve
End Guide
Fiber
End Guide
Insert Parts
Outer Cylindrical Sleeve
V-Groove
Tapered Entrance Hole

Courtesy of GTE Fiber Optics Products.

Four-Rod Splice


Silicone Sleeve (Both Ends)
Stainless Steel Housing
Crimp (Both Ends)
Optaguide Alignment Guide with Substrate
Buffered Fiber

Courtesy of Connector Division, TRW Electronics Components Group.

OPTICAL COMMUNICATIONS DEVICES AND SYSTEMS
UNIT XIV

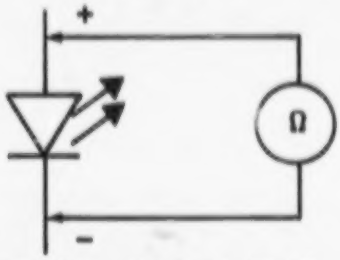
JOB SHEET #1 — USE THE MULTIMETER TO CHECK OPTICAL DIODES

A. Equipment and materials needed

1. Multimeter
2. LED
3. Photodiode

B. Procedure

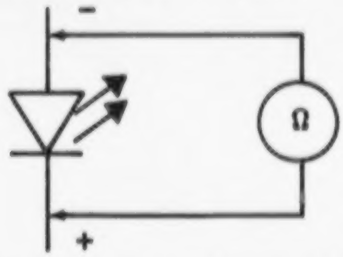
1. Locate the optical diodes designated by your instructor.
2. Connect the multimeter to the LED as shown below.



The ohmmeter measured a resistance value of ____________.

(NOTE: When testing a diode the ohmmeter should be set on the proper scale to prevent application of excessive current and destroying the diode.)

3. Reverse the ohmmeter leads as shown below.



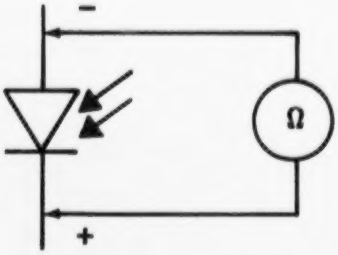
a. The ohmmeter measured a resistance value of ____________.

(NOTE: When testing diodes, the reverse bias measurement should be at least 100 times that of the forward bias reading.)

b. Does the LED check good? ____________

JOB SHEET #1

4. Now connect the multimeter to the photodiode as shown below.



(NOTE: The photodiode must be reversed biased for proper operation.)

5. Cover the photodiode or, in some way, keep the light from the input.

   The ohmmeter measured a resistance value of ____________.

6. Now allow the light to reach the input of the photodiode. If necessary, a flashlight may be used to provide additional light.

   (NOTE: You should receive a high resistance reading when the light is covered; you should receive a low resistance reading when the light is applied.)

   The ohmmeter measured a resistance value of ____________.

7. Using a data manual, determine the resistance values of the photodiode being tested.

   Light value ____________

   Dark value ____________

   Do the above values compare to the measured values in steps 5 and 6? ____________

8. Turn in the lab paper to the instructor.

9. Return equipment and materials to their proper storage location.

OPTICAL COMMUNICATIONS DEVICES AND SYSTEMS
UNIT XIV

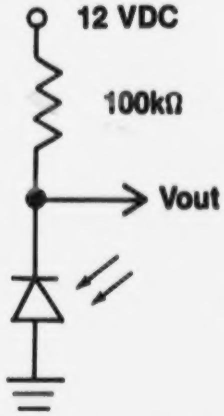
JOB SHEET #2 — CONSTRUCT AND ANALYZE A DETECTOR CIRCUIT

A. Equipment and materials needed

1. Power supply, 12VDC
2. Multimeter
3. Proto board
4. Photodiode
5. Resistors, 470 ohm, 10Kohm, 100K ohm
6. LED
7. Transistor, 2N2222

B. Procedure

1. Construct the circuit shown below.



2. With the photodiode covered so the light will not enter, measure and record the output. ______________

3. Uncover the photodiode and allow varying amounts of light to strike the diode.

   How does this affect the output of the circuit? ______________________________

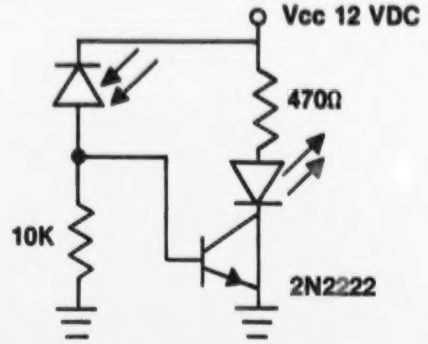
   ____

JOB SHEET #2

4. Now allow maximum light to reach the photodiode and record the reading. ____________

   (NOTE: The above circuit is now working as a voltage divider circuit.)

5. Construct the detector circuit shown below.



6. While observing the LED, block the input to the photodiode.

   What is the condition of the LED? ____________________________

   Why? ____________________________

   ____

7. Now slowly allow the light to the input of the photodiode until maximum light is applied.

   a. What happened to the LED? ____________________________

      ____

   b. Why? ____________________________

      ____

8. Turn in the lab project to the instructor.

9. Return the equipment and materials to their proper storage location.

OPTICAL COMMUNICATIONS DEVICES AND SYSTEMS
UNIT XIV

JOB SHEET #1 PRACTICAL TEST — USE THE MULTIMETER TO CHECK OPTICAL DEVICES

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Correctly connected multimeter to LED.	______	______
3. Correctly measured the LED.	______	______
4. Correctly reconnected the multimeter.	______	______
5. Correctly measured the LED.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______
8. Used proper tools correctly.	______	______
9. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Circuit construction	Correct			Incorrect
	4	3	2	1
Use of data manuals	Used Correctly			Used Incorrectly

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

OPTICAL COMMUNICATIONS DEVICES AND SYSTEMS
UNIT XIV

JOB SHEET #2 PRACTICAL TEST — CONSTRUCT AND ANALYZE A DETECTOR CIRCUIT

STUDENT'S NAME ______________________ DATE __________

EVALUATOR'S NAME ______________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Correctly constructed the circuit.	______	______
3. Obtained proper output values.	______	______
4. Correctly constructed the detector circuit.	______	______
5. Correctly regulated the input to the photodiode.	______	______
6. Obtained proper outputs from the driver.	______	______
7. Checked in/put away tools and materials.	______	______
8. Cleaned the work area.	______	______
9. Used proper tools correctly.	______	______
10. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
11. Practiced safety rules throughout procedure.	______	______
12. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Test equipment	Connected correctly			Connected incorrectly
	4	3	2	1
Photo diodes and LED indications	Properly evaluated			Improperly evaluated

EVALUATOR'S COMMENTS: ______________________________

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

OPTICAL COMMUNICATIONS DEVICES AND SYSTEMS
UNIT XIV

TEST

NAME ______________________ SCORE ______________________

1. Match the terms on the right with their correct definitions.

(NOTE: Terms and definitions continue on next page.)

______a. The ability of a fiber to be stretched or pulled without breaking

______b. A method of carrying information from one point to another using a thin strand of glass or plastic which carries light instead of electricity

______c. The distance a sine wave travels in a cycle ($\lambda = v/f$)

______d. A device used to connect or disconnect optical devices such as the source, detector, or fibers

______e. An imaginary line perpendicular to the connecting line between the core material and the cladding material

______f. Where the refracted signal is 90° from the normal

______g. The outer sheath that insulates and protects cabling against the environment

______h. In optical fiber this is the deflection of light

______i. A phenomena that causes broadening or spreading of light as it propagates through an optical fiber

______j. Inherent and measurable properties that will vary the ability of something

______k. The path that light will follow when transmitted through an optical fiber

1. Attenuation
2. Beamsplitter
3. Characteristics
4. Cladding
5. Connector
6. Coupler
7. Critical angle
8. Dispersion
9. Fiber optics
10. Fiberscope
11. Graded-index fiber
12. Index of refraction

TEST

_____l. The layer that surrounds the fiber core and contains a lower index of refraction

_____m. A loss of signal amplitude during transmission

_____n. The velocity of electromagnetic energy in a vacuum (186,000 mi/sec)

_____o. A glass rod utilized in medicine to look inside the body

_____p. Dispersion resulting from different transit lengths of various propagating modes causing the various signals to exit at different times

_____q. A ratio of the velocity of light in free space to the velocity of light in a specific material

_____r. A device used to make permanent connections between different fibers

_____s. Fiber that consists of various layers of fiber, similar to the rings of a tree trunk

_____t. A device that divides or combines light signals as required

_____u. A light splitting device using a plate coated with a partially reflective material where a portion of the light transmits through the plate and a portion is reflected

13. Jacket
14. Mode
15. Modal dispersion
16. Normal line
17. Refraction
18. Speed of light
19. Splice
20. Tensile strength
21. Wavelength

TEST

2. Match abbreviations related to optical communications devices and systems on the right with their correct definitions.

_____a. Light amplification of simulated emission of radiation

_____b. Transmitter

_____c. Frequency

_____d. Numerical aperature

_____e. Plastic-clad silica (glass)

_____f. Wavelength division multiplexing

_____g. Ohms

_____h. Wavelength

_____i. Terahertz (1,000,000,000,000 HZ)

_____j. Receiver

_____k. Pulse coded modulation

_____l. Dry, no polish

_____m. Velocity of the sine wave

_____n. Hertz

1. WDM
2. PCM
3. TX
4. RX
5. THz
6. Hz
7. λ
8. V
9. f
10. PCS
11. NA
12. LASER
13. DNP
14. Ω

3. Match stages of a TX/TX optical communication system on the right with their correct descriptions.

_____a. A thin cable of glass or plastic used to transmit light signals from one point to another

_____b. Amplifies the receiver signal from the detector and sends this signal

_____c. A photodiode used to convert the light pulses transmitted by the source back into a modulated signal at the receiver

_____d. Receives the signal from the user equipment and converts the signal to a modulation code

_____e. Consists of either an LED or a laser diode which transmits light pulses in comparison to the modulated signal received from the driver

1. Driver
2. Source
3. Optical cable
4. Detector
5. Amplifier

TEST

4. Match types of optical communications on the right with their correct uses.

_____a. A process of sending signals through glass for long distances, used widely in communications

_____b. A device that amplifies lightwaves and concentrates them in a narrow, very intense beam

_____c. A series of lenses and mirrors creating light modulation due to the voice vibrating the mirror

_____d. Light signals traveling through a stream of water, even going around corners

_____e. Glass rods carrying images such as the fiberscope

_____f. Used by the Bostonians for Paul Revere's ride

_____g. Used by navy signalmen and lighthouses

_____h. A communication system that connected Boston and Martha's Vineyard

1. Lanterns
2. Lamps
3. Optical telegraph
4. Internal reflections
5. Photophone
6. Glass rods
7. Laser
8. Fiber optics

5. Complete the following statements concerning advantages of optical communications by inserting the word(s) which best complete(s) each statement.

a. Information carrying ability increases with increased _____________ .

b. Information carrying ability increases with increased carrier frequency which for fiber optics is about _____________ .

c. Power loss or attenuation in coaxial cable _____________ with frequency where optical cable loss remains _____________ with frequency increases.

d. Losses require additional _____________ in the transmission line; since fiber optics have less loss, fewer _____________ are required.

e. Fiber-optic cable is immune to _____________ _____________ so fiber optics can be run beside other cables with no interference.

f. Fiber-optic cable does not radiate energy, thus making it virtually impossible to _____________ without detection.

TEST

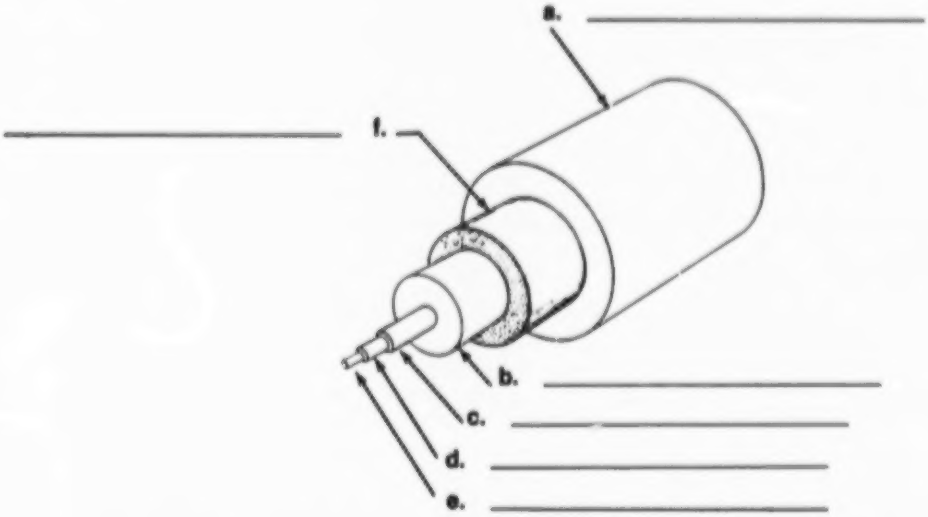
g. A fiber-optic cable is ____________ than a copper cable, thus allowing several ____________ cables to be run in the same space as one ____________ cable.

h. For the same transmission requirements the weight of fiber-optic cable would be approximately ____________ lbs/1000 ft. where copper would be approximately ____________ lbs/1000 ft.

i. Fiber optics transmit only light, thus there is no electrical ____________, no ____________ for fire, and they can be run safely through ____________ or other hazardous areas.

j. Fiber optics are ____________ due to less cables being necessary, they are lighter in weight, need fewer repeaters, and carry more signals with less interference than standard cables.

6. Identify the parts of a fiber-optic cable.



7. Complete the following statements concerning characteristics of light transmission through optical fiber by inserting the word which best completes each statement.

a. Light passing from a lower refractive index (n2) to a higher one (n1) causes the angle of refraction to ____________ or is bent toward the normal.

b. Light passing from a higher refractive index (n1) to a lower one (n2) causes the angle of refraction to ____________ or is bent away from the normal or toward the critical angle.

TEST

c. When the angle of incidence causes the angle of refraction to increase above the critical angle, ____________ occurs.

d. The ____________ the difference of indices, the greater amount of the light will be reflected.

8. Match types of optical cables on the right with their correct performance.

_____a. Consists of a glass core with a plastic cladding

_____b. Constructed of a plastic core and a plastic cladding

_____c. The use of glass PCS and plastic fiber in one cable causes light signals to use different paths causing modal dispersion

_____d. By using graded index fiber with each ring outward having a lower index of refraction, the modes do not interact

_____e. By using only one mode, modal dispersion does not exist and the signal will be more efficient

1. Single mode
2. Graded index
3. Step-index glass
4. PCS
5. Plastic

9. Complete the following statements concerning characteristics of optical fiber by inserting the word(s) which best complete(s) each statement.

a. ____________ may be modal, material, or waveguide.

b. ____________ is a loss of signal power as light travels through a fiber-optic cable.

c. ____________ is a loss of energy due to imperfections in the fiber cable.

d. ____________ is a loss in power caused by impurities in the fiber converting optical power into heat.

e. ____________ ____________ is caused by bumps in the core-to-cladding interface creating angles that will not allow the light to reflect or cables with too sharp a bend radius.

f. ____________ ____________ is the light gathering ability of the fiber, or light injected into the fiber at angles greater than the critical angle.

g. The ____________ ____________ of a fiber is greater than that of metal cable, but microscopic cracks and flaws of fiber cause fiber weakness.

TEST

h. The ____________ ____________ of fiber glass cable must be five times the cable diameter for unstressed cable and ten times the diameter for stressed cable or the fiber will snap.

i. Optical fibers are unaffected by ____________ ____________ except for any increase in attenuation when subjected to high levels of continuous ____________, but within seconds after the ____________ clears fiber cables are operational.

10. Distinguish between loss factors of optical cables by placing an "I" for internal factors in the blanks next to the correct factors.

_____a. Lateral displacement

_____b. End separation

_____c. NA mismatch

_____d. Concentricity

_____e. Angular misalignment

_____f. Ellipticity

_____g. Cladding diameter mismatch

_____h. Core diameter mismatch

_____i. Surface finish should be smooth

11. List four types of connectors used with fiber-optic cable.

a. ____

b. ____

c. ____

d. ____

12. List five ideal requirements of optical connectors.

a. ____

b. ____

c. ____

d. ____

e. ____

TEST

13. List three types of splices used with fiber-optic cable.

a. ______________________________

b. ______________________________

c. ______________________________

14. Complete the following statements concerning the basic coupler operation by inserting the word(s) that best complete(s) each statement.

a. The arrows indicate the possible directions of ____________ ____________ through a coupler.

b. Light injected into parts one and four will only appear through parts ____________ and ____________.

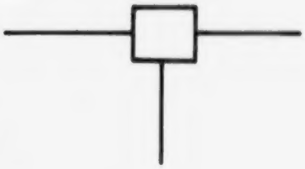
c. Light injected into parts two and three will only appear through parts ____________ and ____________.

d. The coupler is a ____________ device.

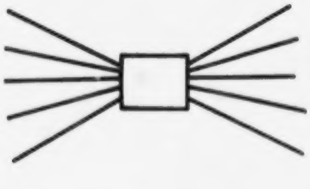
e. The part across from the input is the ____________, while the other part is the ____________ part.

f. The ____________ contains the greater power output.

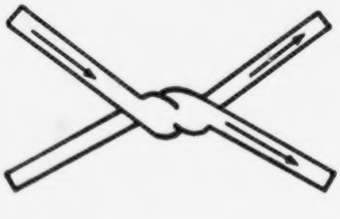
15. Identify the following types of couplers used in fiber optics.



a. ____________________

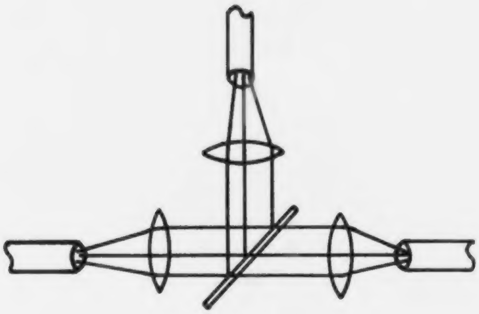


b. ____________________



c. ____________________

TEST



d. ______________________________

16. List four areas of optical cable installation.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.

17. Demonstrate the ability to:

    a. Use the multimeter to check optical diodes. (Job Sheet #1)

    b. Construct and analyze a detector circuit. (Job Sheet #2)

OPTICAL COMMUNICATIONS DEVICES AND SYSTEMS
UNIT XIV

ANSWERS TO TEST

1. a. 20
   b. 9
   c. 21
   d. 5
   e. 16
   f. 7
   g. 13
   h. 17
   i. 8
   j. 3
   k. 14
   l. 4
   m. 1
   n. 18
   o. 10
   p. 15
   q. 12
   r. 19
   s. 11
   t. 6
   u. 2

2. a. 12
   b. 3
   c. 9
   d. 11
   e. 10
   f. 1
   g. 14
   h. 7
   i. 5
   j. 4
   k. 2
   l. 13
   m. 8
   n. 6

3. a. 3
   b. 5
   c. 4
   d. 1
   e. 2

4. a. 8
   b. 7
   c. 5
   d. 4
   e. 6
   f. 1
   g. 2
   h. 3

5. a. Bandwidth
   b. THZ
   c. Increases, steady
   d. Repeaters, repeaters
   e. Electromagnetic radiation
   f. Tap
   g. Smaller, fiber-optic, copper
   h. 9, 80
   i. Shock, sparks, fuel tanks
   j. Cheaper

6. a. Black polyurethane outer jacket
   b. Buffer jacket
   c. Silicone coating
   d. Cladding
   e. Core
   f. Strength members

ANSWERS TO TEST

7. a. Decrease
   b. Increase
   c. Reflection
   d. Higher

8. a. 4
   b. 5
   c. 3
   d. 2
   e. 1

9. a. Dispersion
   b. Attenuation
   c. Scattering
   d. Absorption
   e. Microbend loss
   f. Numerical aperature
   g. Tensile strength
   h. Bend radius
   i. Nuclear blasts, radiation, radiation

10. c, d, f, g, h

11. a. Ribbon cable array connector
    b. SMA connectors
    c. Plastic-ferrule simplex connector
    d. DNP connector

12. a. Low power loss
    b. Easy installation
    c. Connect/disconnect repeatedly
    d. Loss consistency
    e. Economical

13. a. Fusion splice
    b. Elastomeric splice
    c. Four-rod splice

ANSWERS TO TEST

14. a. Signal flow
    b. Two, three
    c. One, four
    d. Bidirectional
    e. Throughpart, top
    f. Throughpart

15. a. Tee connector
    b. Star connector
    c. Fused couplers
    d. Beamsplitter

16. a. Direct burial installation
    b. Aerial installation
    c. Conduit
    d. Cable trays

17. Performance skills evaluated to the satisfaction of the instructor

TELEPHONE SYSTEMS
UNIT XV

UNIT OBJECTIVE

After completion of this unit, the student should be able to analyze telephone systems and circuits such as telephone centers, local lines, trunk lines, and system standards. Competencies will be demonstrated by completing the job sheets and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to telephone systems with their correct definitions.
2. Match abbreviations related to telephone systems with their correct meanings.
3. Match types of communication facilities with their correct descriptions.
4. Match telephone centers with their correct classes.
5. Distinguish between communication paths used in telephone systems.
6. Complete statements concerning local loop functions of telephone systems.
7. Match types of branch exchanges with their correct descriptions.
8. Match functions of a PBX key system with their correct descriptions.
9. Distinguish among telephone dialing methods.
10. Complete statements concerning ringer equivalence requirements.

OBJECTIVE SHEET

11. Match telephone system characteristics with their correct voltage and/or frequency requirements.
12. Distinguish among private line services.
13. Complete chart characteristics of subscriber line color codes.
14. Complete statements concerning telephone number codes.
15. Complete statements concerning local loop cable characteristics.
16. List transmission parameters.
17. Complete statements concerning types of line conditioning.
18. Demonstrate the ability to:
    a. Analyze noise on a telephone system. (Job Sheet #1)
    b. Measure the ring signal of a telephone system. (Job Sheet #2)

TELEPHONE SYSTEMS
UNIT XV

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to class to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information sheet.

F. Discuss information sheet.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

   1. Demonstrate the testing of various communication signals.
   2. Discuss various types of noise measurement.
   3. Show students methods of cable types and connectors at the user facilities.
   4. Review other types of test equipment.
   5. Discuss cable color codes.
   6. Take students on tours of various types of communication facilities.
   7. Invite representatives from various telephone facilities to talk to the class about telephone systems.
   8. Review safety procedures prior to completing the job sheets.
   9. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN WRITING THIS UNIT

A. Sherman, Ken. *Data Communication, A User's Guide*. Second Edition. Reston, VA: Reston Publishing Co., 1985.

B. Tomasi and Absouskas. *Telecommunications Voice/Data With Fiber Optic Applications*. First Edition. Englewood Cliffs, NJ: Prentice Hall, 1988.

C. *Understanding Telephone Electronics*. Fort Worth, TX: Radio Shack.

D. *Installing Your Own Telephones*. Fort Worth, TX: Radio Shack.

TELEPHONE SYSTEMS
UNIT XV

INFORMATION SHEET

I. **Terms and definitions**

A. Branch exchange — A switchboard located between the cable termination box and the central office to route the incoming lines

B. Cable pair — The line between the cable termination box and the user which consists of two conductors

C. Codec — One circuit used both as an encoder and a decoder

D. Demarche — A connection device at the user facility where the local loop ends and the user equipment begins

E. Ground start — An off-hook condition which causes a ground to be applied to half of the line relay, then when the dial tone is detected by the PBX equipment the ground start contact is opened

F. Key system — A part of the PBX system which provides for centralized control of telephone functions such as intercom and paging

G. Loop start — An off-hook condition applying current to the line which in turn activates a relay closing the relay contacts signaling the switching circuits

H. Off-hook — The process of lifting the handset off the telephone, completing a DC path alerting the central office of an off-hook condition (loop start condition)

I. On-hook — The process of returning the handset to the telephone, opening the switch hook

J. Protector — An overvoltage protection device for voltage and lightning surges of up to 1000 volts

K. Subscriber — The operator or user of the transmit/receive instrument (Transparency 1)

L. Tip and ring — Refers to the tip and ring of the telephone plug

II. **Abbreviations related to telephone systems**

A. PBX — Private Branch Exchange

B. BORSCHT — Battery, Over voltage protection, Ring voltage, Supervision, Coding, Hybrid, and Testing

INFORMATION SHEET

C. PABX — Private Automatic Branch Exchange

D. CBX — Computerized Branch Exchange

E. SPC — Stored Program Control

F. MODEM — Modulator/Demodulator

G. CODEC — Coder/Decoder

H. DTMF — Dual Tone Multifrequency

I. REN — Ringer Equivalence Number

J. SF — Single Frequency

K. FCC — Federal Communications Commission

L. BW — Bandwidth

M. Telco — Telephone Company

N. POTS — Plain Old Telephone Service

O. PSTN — Public Service Telephone Network

III. **Types of communication facilities**

A. Instrument — The device used by the subscriber to transmit and receive signals, such as the telephone or computer terminal (Transparency 1)

B. Cable termination box — The interconnection point within the local loop where the two wire subscriber lines and the multi-cable lines are connected (Transparency 2)

C. Modem — An electronic circuit used to convert analog to digital or digital to analog signals (Transparency 2)

D. Central office — The local switch where the subscriber equipment is interconnected to the appropriate path whether to another central office, to a tandem switch, or to a toll center (Transparencies 2 and 3)

E. Tandem switch — A switching center where the local switch will transfer a call when lines directly between local switches are unavailable (Transparency 3)

F. Toll center — A switching center that receives long distance transmissions from the central office and connects to another toll center when possible; if no circuits are available, then it connects to a primary center (Transparency 4)

INFORMATION SHEET

G. Primary center — Transfers the transmission to a sectional center or regional center in order to complete the transmission (Transparency 4)

H. Sectional center — The sectional center tries to transmit back to a different primary center in order to complete the transmission (Transparency 4)

I. Regional center — The switching center where the transmission comes to when all other paths are being used as a final route (Transparency 4)

IV. **Classes of telephone centers** (Transparency 4)

A. Class 1 — Regional centers

B. Class 2 — Sectional centers

C. Class 3 — Primary centers

D. Class 4 — Toll centers

E. Class 5 — Central office

V. **Communication paths** (Transparency 2)

A. Local loop — The interconnecting cable from the subscriber's facility to the central office

B. Trunk lines — The interconnecting lines between the central offices, tandem switches, the various centers, and can be between the PBX and the central office

VI. **Local loop functions** (BORSCHT)

A. A battery voltage for subscriber phone systems, usually 48 VDC

B. An overvoltage protection device for voltage and lightning surges of up to 1,000 volts

C. A ring voltage of 50-90 V at 70-100 hertz to indicate a call is waiting

D. A supervision device which detects line requests such as off-hook conditions and controlling calls in progress

E. Equipment which codes the voice signals into serial digital codes and then decodes the signals at the receiver

F. A hybrid transformer network which is used to convert two-wire to four-wire and four-wire to two-wire for long distance transmission (Transparency 5)

G. Testing of the circuit, provided through relays placed within the local loop circuitry

INFORMATION SHEET

VII. **Types of branch exchanges** (Transparency 6)

A. PBX — A manual device where the operator must use jacks and patchcards to establish communications

B. PABX — An exchange using stepper switches and crossbars

C. EPABX — The mechanical matrices were exchanged with electronic matrices or switches and may use either analog or digital switching

D. CBX — The switching in the exchange is controlled by digital computers

E. SPC — Also a computer controlled exchange but uses stored programs for control

VIII. **Functions of a PBX key system**

A. Call forwarding — If a particular number is called it rings at a location designated by the user

B. Call waiting — An indication to the user that another call is waiting by transmitting a click or tone

C. Camp on — If the line is busy the second incoming call will wait until the receiver is on-hook then ring immediately

D. Call forward, no answer — After a predetermined number of rings the call is transferred to another extension or sent back to the operator

E. Hunt group — One number is dialed but the call is put through to the next available extension of a group

F. Speed dialing — By dialing from two to four digits, frequently called numbers are automatically dialed

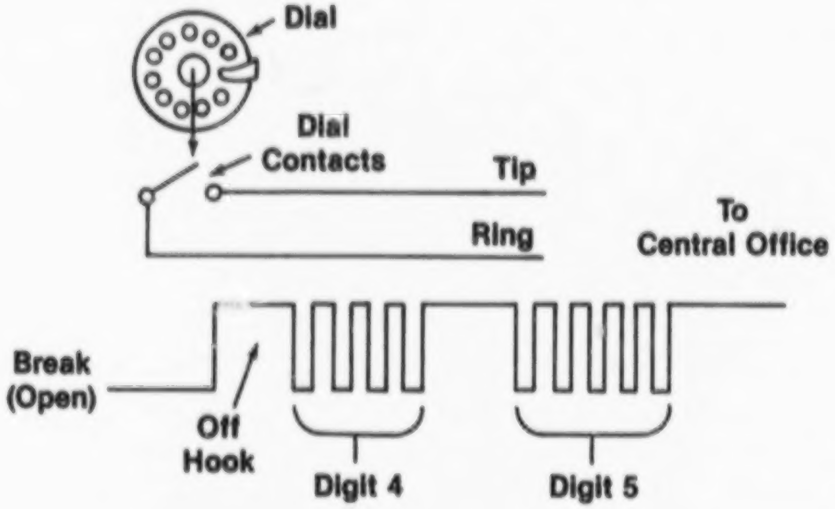
(NOTE: Many other functions are available from the local phone company.)

INFORMATION SHEET

IX. Telephone dialing methods

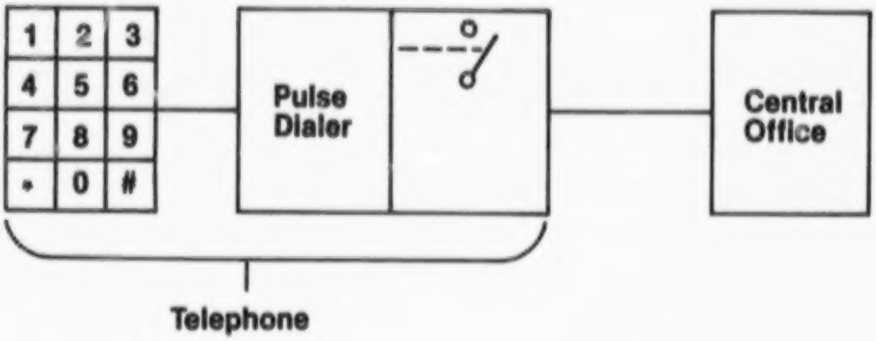
A. Pulse dialing — A rotary dial which when released, its rotation opens and closes a switch which creates loop current pulses according to the number dialed

Example:


Dial
Dial Contacts
Tip
Ring
To Central Office
Break (Open)
Off Hook
Digit 4
Digit 5

B. Electronic pulse dialing — The mechanical switch is replaced by an electronic circuit, a pulse dialer, that creates the loop current pulses

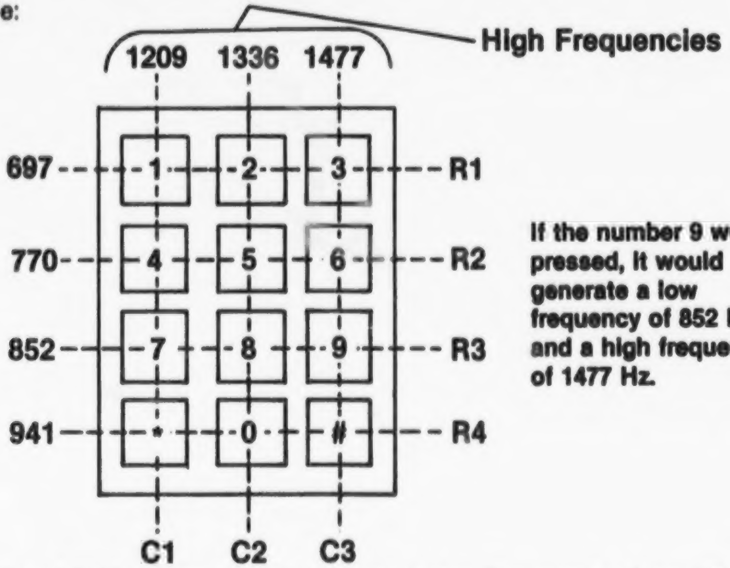
Example:


1 2 3
4 5 6
7 8 9
* 0 #
Pulse Dialer
Central Office
Telephone

INFORMATION SHEET

C. Dual tone multifrequency — A key pad in which low frequencies are applied horizontally and high frequencies are applied vertically, thus transmitting a low and high frequency for each key depressed

Example:



If the number 9 were pressed, it would generate a low frequency of 852 Hz and a high frequency of 1477 Hz.

(NOTE: The DTMF dialing system is much faster. The number 9 on DTMF will take 50m seconds for the tones and 50m seconds interval, where the pulse dialing takes 40m seconds for each pulse and 60m seconds interval which is 100 m seconds times nine which would be 900m seconds compared to 100 m seconds for DTMF.)

X. **Ringer equivalence requirements**

(NOTE: The FCC requires certain information to be on telephones. The REN is one of these items.)

A. The REN number for most phones will usually be less than one.

B. A maximum of five REN ringing power is supplied by the Central office.

C. If the maximum ringing power is exceeded, the telephones may not ring.

D. The suffix of A on the REN number represents the old single party line of 20 ± 3 Hz and 30 ± 3 Hz (i.e. REN 0.07A)

E. The suffix of B on the REN number represents the new frequency of 15.3 Hz to 68 Hz. (i.e. REN 0.07B)

INFORMATION SHEET

XI. Voltage and frequency requirements

A. Subscriber loop voltage — 48 VDC to 52 VDC

B. Ring voltage — 70-100 V at 16-60 Hz

C. A REN frequency — 20 ± 3 Hz and 30 ± 3 Hz

D. B REN frequency — 15.3 Hz to 68 Hz

E. Station busy signal — 60 ipm buzz

F. Equipment busy signal — 120 ipm buzz

G. Voice frequencies — 300 to 3000 Hz

H. Allocated voice frequency BW — 0-4 KHz

XII. Telephone private line services

(NOTE: Telephone companies offer an assortment of private line services to the customer. Subscribers lease these facilities as needed.)

A. Dedicated lines — Consist of voice communication lines for station to station use (PSTN)

B. Private lines — Lines leased by the subscriber on a 24 hour time period and are constantly available

C. Leased lines (Foreign exchange) — The subscriber leases a loop to a dial switch of their choice which is constantly available and allows toll free calling

INFORMATION SHEET

XIII. **Subscriber line color codes** — The most common color codes of subscriber lines are red, green, yellow, and black and are usually four-conductor telephone cables, but can be six conductor cables

Example:

Conductors					
4		6		6	
R*	T**	R	T	R	T
Red	Green	Red	Green	Blue	White/Blue Band
Yellow	Black	Yellow	Black	Orange	White/Orange Band
		Blue	White	Green	White/Green Band
		Red	Green	Blue/White Band	White/Blue Band
		Yellow	Black	Orange/White Band	White/Orange Band
		Blue/White Band	White/Blue Band	Green/White Band	White/Green Band

*R = RING
**T = TIP

XIV. **Telephone number codes**

A. The number dialed by the subscriber indicates where the call is destined to go.

Example: 1-918-455-0202

B. The four digit number is the extension number in a particular zone.

C. The three digit prefix, 455, is the zone or central office in a specific community served.

D. The single digit one or zero indicates the call is no longer limited to a particular zone and transfers the call to a toll center.

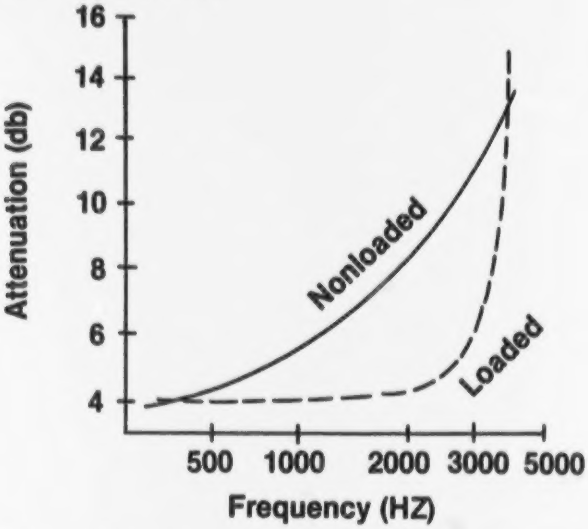
E. The three digit prefix, 918, indicates a different zone than the one where the call originated and indicates what zone to contact.

INFORMATION SHEET

XV. Local loop cable characteristics

(NOTE: Due to effects of conductance and capacitance felt along the length of the cable pairs, which creates an attenuation to higher frequencies, inductors are added in series with the wire. This is called loading. To determine the characteristics of the cable the following codes are used.

Example: A 26H88 cable



A. The first group of numbers represent the wire gauge.

B. The letter indicates the length in feet.

   1. H — 6000 ft.
   2. D — 4500 ft.
   3. B — 3000 ft.

C. The last group of numbers represents the inductance value.

   1. 44 mh
   2. 88 mh
   3. 135 mh

INFORMATION SHEET

XVI. **Transmission parameters**

A. Bandwidth parameters

1. Attenuation distortion
2. Envelope delay distortion

B. Interface parameters

1. Terminal impedance
2. In-band and out-of-band signal power
3. Test signal power
4. Ground isolation

C. Facility parameters

1. Noise measurements
2. Frequency and phase distortion
3. Amplitude distortion
4. Nonlinear distortion

XVII. **Types of line conditioning**

(NOTE: The telephone company offers various types of line conditioning whose specifications have been set up by FCC Tariff #260.)

A. C-type conditioning specifies the maximum limits for attenuation distortion and envelope delay distortion.

1. C1 and C2 conditioning pertain to two-point and multipoint circuits.
2. C3 conditioning pertains to access lines and trunk circuits.
3. C4 conditioning pertains to two-point and multipoint circuits with a maximum of four stations.
4. C5 conditioning pertains to two-point circuits only.

INFORMATION SHEET

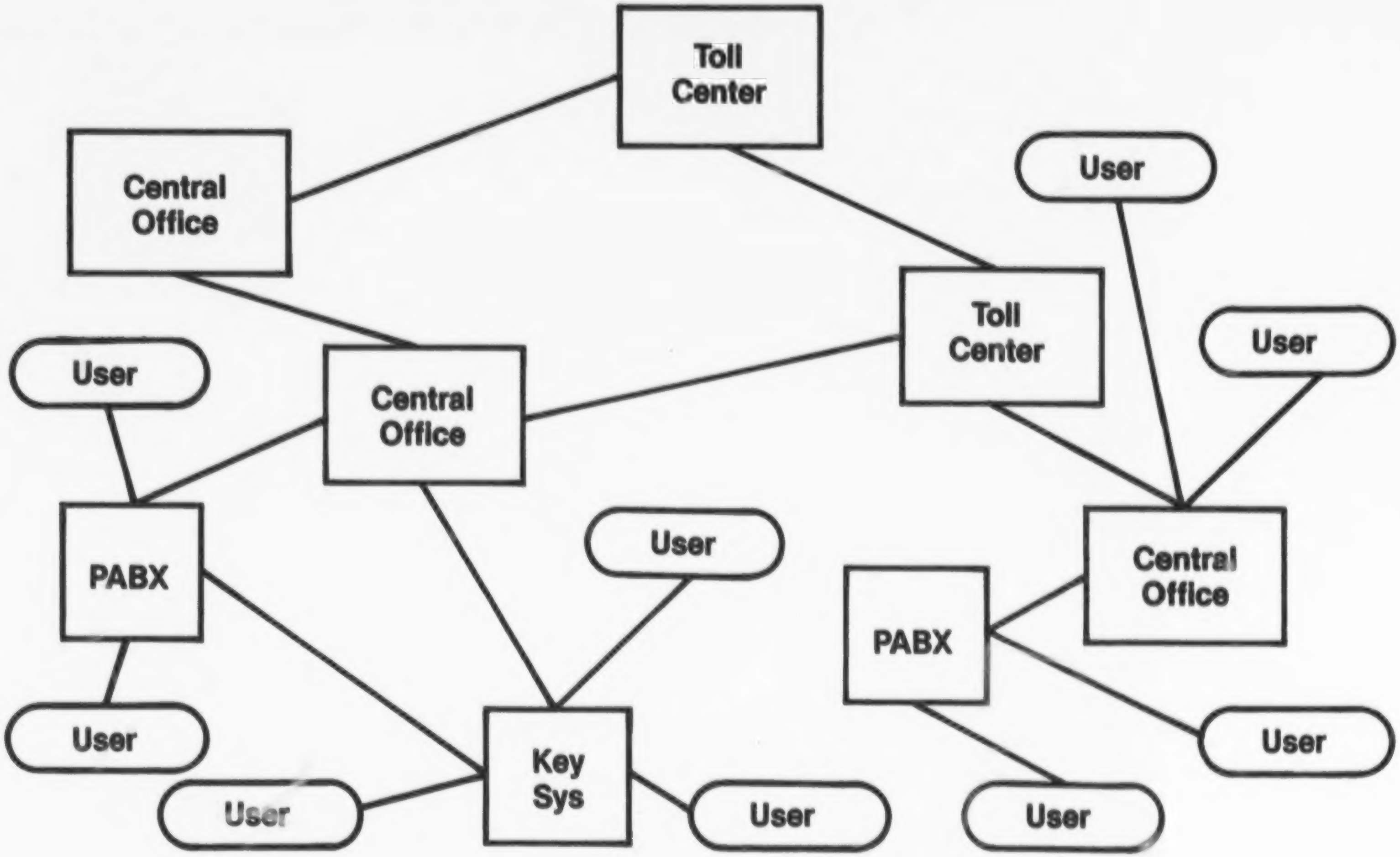
B. D-type conditioning sets the minimum requirements for signal-to-noise ratio and deals with nonlinear distortion.

   1. D-type conditioning is necessary with a faster data transmission rate beginning at approximately 4800 bps.

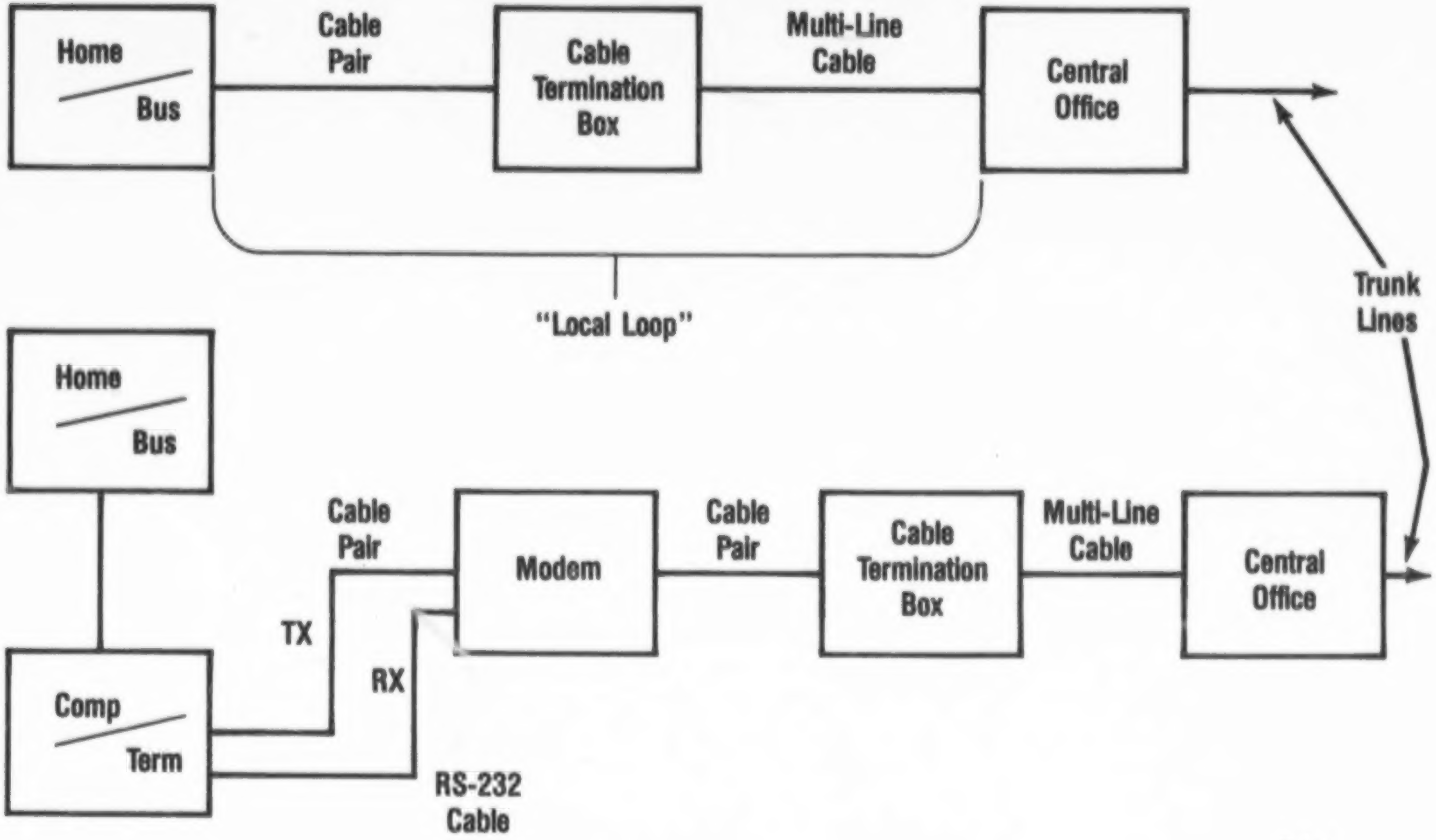
   2. D1 conditioning is used for two-point circuits.

   3. D2 conditioning is used for multipoint circuits.

Subscriber Telephone System


Toll Center
Central Office
User
Toll Center
User
User
Central Office
PABX
User
Central Office
PABX
User
User
Key Sys
User
User
User

Local Telephone System



Home / Bus

Cable Pair

Cable Termination Box

Multi-Line Cable

Central Office

"Local Loop"

Trunk Lines

Home / Bus

Comp / Term

TX

RX

RS-232 Cable

Cable Pair

Modem

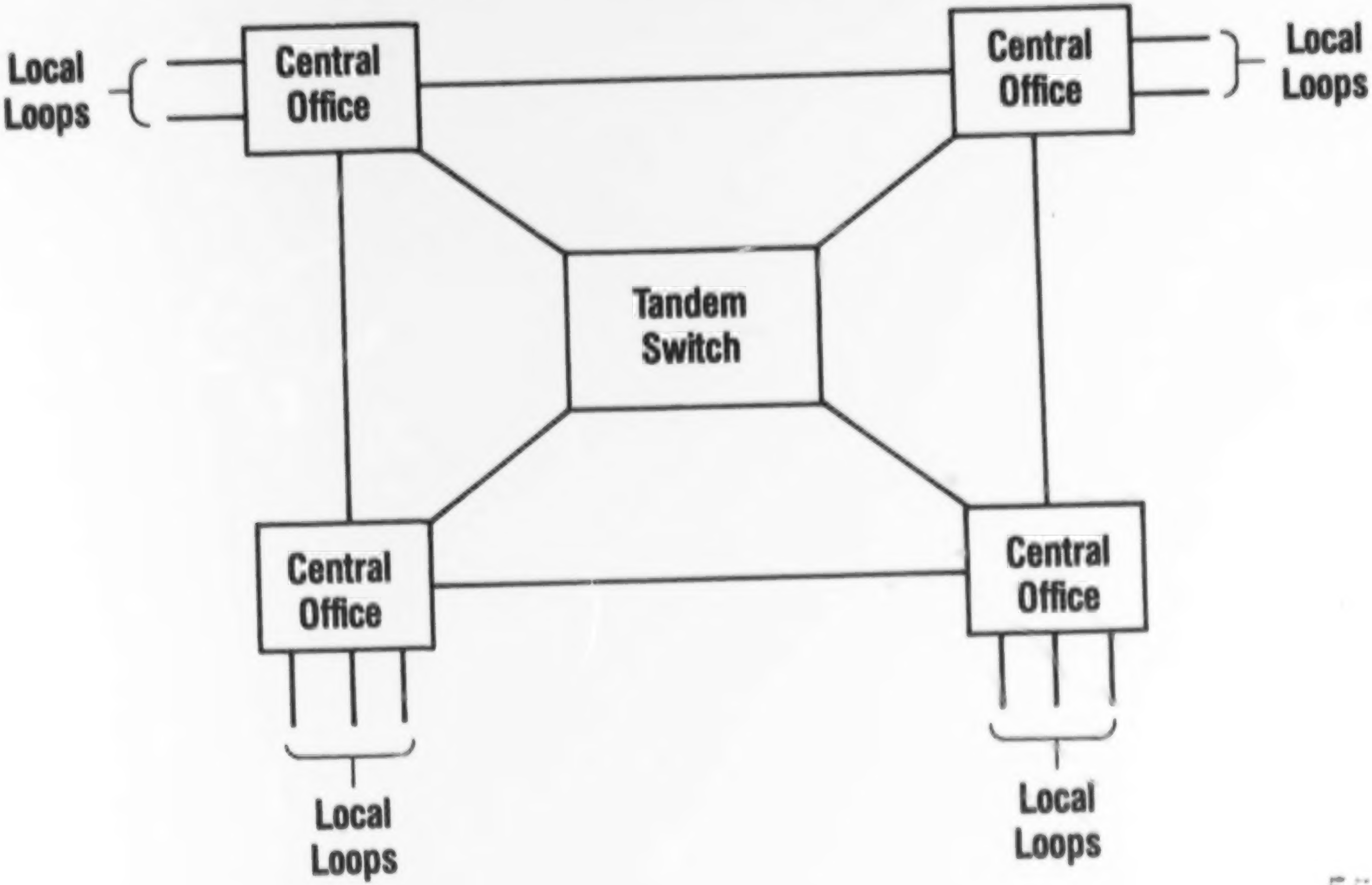
Cable Pair

Cable Termination Box

Multi-Line Cable

Central Office

Zone Telephone System



Central Office

Central Office

Tandem Switch

Central Office

Central Office

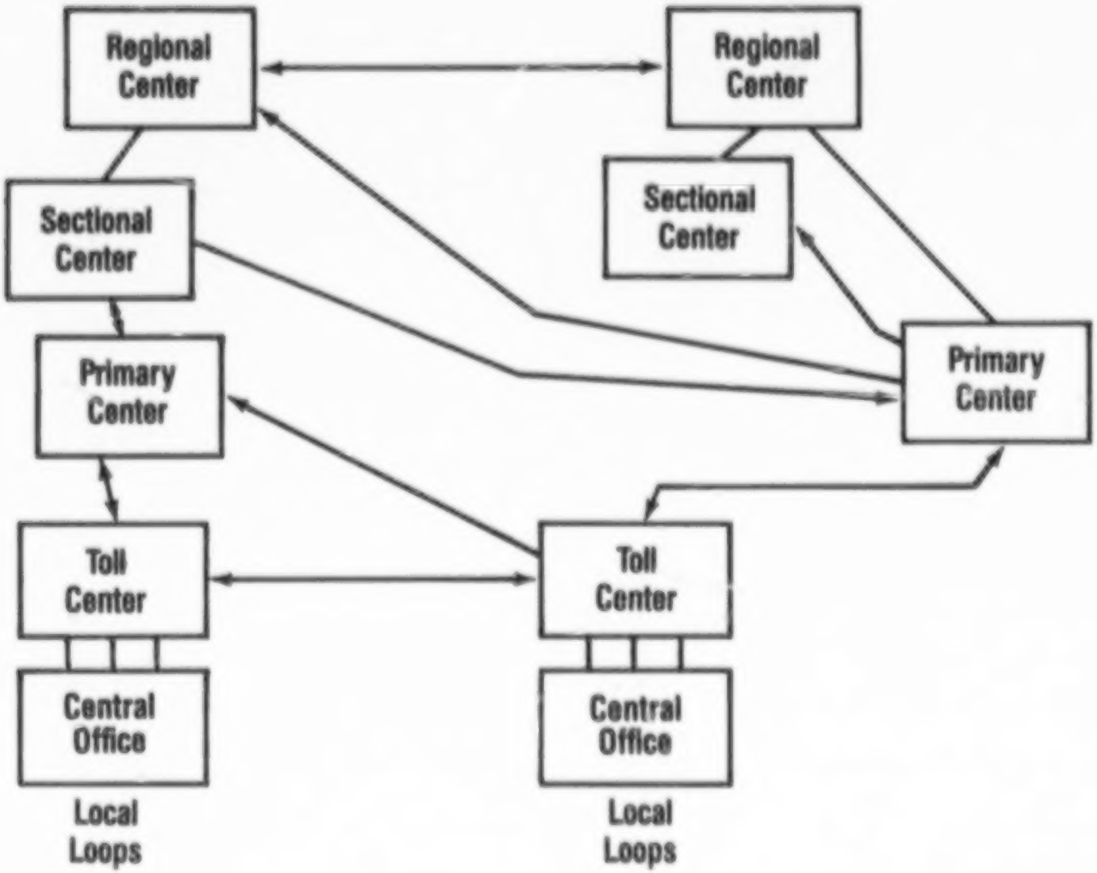
Local Loops

Local Loops

Local Loops

Local Loops

Telephone Switching System



Regional Center

Regional Center

Sectional Center

Sectional Center

Primary Center

Primary Center

Toll Center

Toll Center

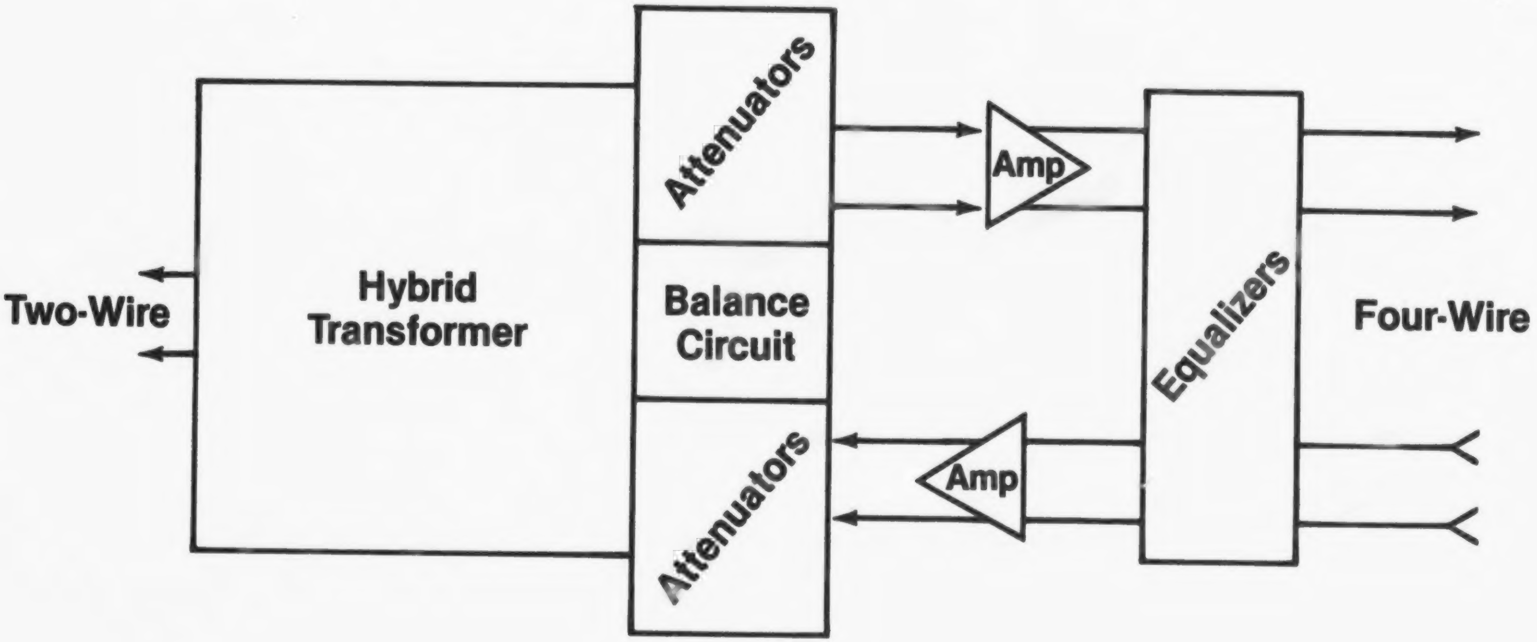
Central Office

Central Office

Local Loops

Local Loops

Hybrid Network


Two-Wire
Hybrid Transformer
Attenuators
Balance Circuit
Attenuators
Amp
Amp
Equalizers
Four-Wire

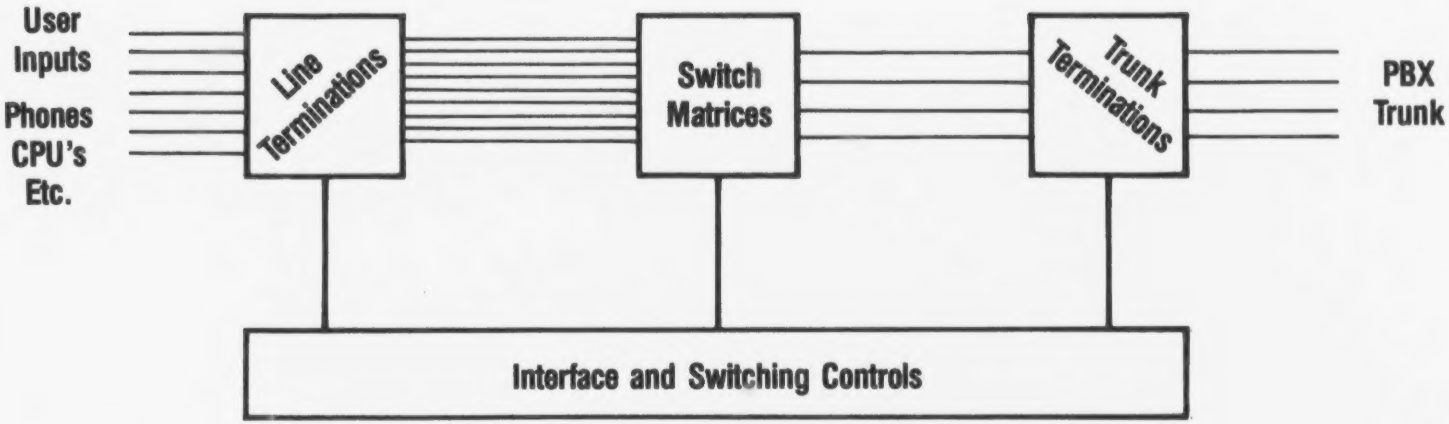
561

TM 5

560

CE-575

PBX System



User Inputs
Phones
CPU's
Etc.

Line Terminations

Switch Matrices

Trunk Terminations

PBX Trunk

Interface and Switching Controls

TELEPHONE SYSTEMS
UNIT XV

JOB SHEET #1 — ANALYZE NOISE ON A TELEPHONE SYSTEM

A. Equipment and materials needed

1. Signal generator
2. Notch filter
3. C-message filter
4. dB or milliamp meter (must have input isolator from ground)
5. Various test leads

B. Procedure

1. Locate the equipment and materials required.
2. Turn on the signal generator and adjust the output for a 1004 Hz tone at the test tone level.
3. Contact the telephone personnel at the distant end.
4. Have them connect the notch filter and the dB meter.
5. Connect the signal generator to the transmit equipment and transmit the 1004 Hz signal to the distant end.

   (NOTE: Connecting the notch filter to the receive end of the circuit removes the test tone and allows the noise to be measured.)
6. After the noise has been measured, remove the equipment at both ends and restore the equipment to operation.
7. Determine what an acceptable noise level should be.
8. When completed, turn the lab project in to the instructor.
9. Return the equipment and materials to their proper storage location.

TELEPHONE SYSTEMS
UNIT XV

JOB SHEET #2 — MEASURE THE RING SIGNAL OF A TELEPHONE SYSTEM

A. Equipment and materials needed

1. Multimeter (can be part of telephone system)
2. Frequency counter
3. Various test leads

B. Procedure

1. Review safety precautions including personal and equipment safety.
2. Locate the equipment and materials required.
3. Adjust the multimeter for a range that will measure between 50 and 90 volts.
4. Connect the multimeter to the receive line of the telephone equipment.
5. Upon receipt of a ring signal, measure the voltage reading.

   (NOTE: The normal ring voltage for telephone equipment should be between 50 and 90 volts. For a definite voltage, check with your particular telephone company.)

6. Adjust the frequency counter for a frequency between 16 and 60 Hz.
7. Connect the frequency counter to the receive line of the equipment.
8. Upon receipt of a ring signal, measure the frequency reading.

   (NOTE: Usually when checking communication lines, communication is established between distant offices.)

9. Upon completion of testing, remove the equipment and restore equipment to operation.
10. When completed, turn in the lab project to the instructor.
11. Return the equipment and materials to their proper storage location.

TELEPHONE SYSTEMS
UNIT XV

JOB SHEET #1 PRACTICAL TEST — ANALYZE NOISE ON A TELEPHONE SYSTEM

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ____________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Properly adjusted appropriate test equipment.	______	______
3. Located the correct circuits for measurement.	______	______
4. Properly connected the test equipment for measurement.	______	______
5. Properly reestablished communications.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______
8. Used proper tools correctly.	______	______
9. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Evaluation of test reading	Correct			Incorrect
	4	3	2	1
Equipment hookup	Proper procedure followed			Did not follow proper procedure
	4	3	2	1
Noise level	Acceptable			Unacceptable

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TELEPHONE SYSTEMS
UNIT XV

JOB SHEET #2 PRACTICAL TEST — MEASURE THE RING OF A TELEPHONE SYSTEM

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Set up equipment to measure ring voltage and frequency.	______	______
3. Correctly connected the test equipment for evaluation.	______	______
4. Correctly determined if the ring values were correct.	______	______
5. Properly reestablished communications.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______
8. Used proper tools correctly.	______	______
9. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Ring measurements	Correct			Incorrect

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY
4 — Skilled — Can perform job with no additional training. 3 — Moderately skilled — Has performed job during training program; limited additional training may be required. 2 — Limited skill — Has performed job during training program; additional training is required to develop skill. 1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

TELEPHONE SYSTEMS
UNIT XV

TEST

NAME ______________________ SCORE ______________________

1. Match the terms on the right with their correct definitions.

_____a. One circuit used both as an encoder and a decoder

_____b. The process of returning the handset to the telephone, opening the switch-hook

_____c. The operator or user of the transmit/receive instrument

_____d. The line between the cable termination box and the user which consists of two conductors

_____e. A switchboard located between the cable termination box and the central office to route the incoming lines

_____f. An off-hook condition which causes a ground to be applied to half of the line relay, then when the dial tone is detected by the PBX equipment, the ground start contact is opened

_____g. An off-hook condition applying current to the line, which in turn activates a relay closing the relay contacts signaling the switching circuits

_____h. An overvoltage protection device for voltage and lightning surges of up to 1000 volts

_____i. A connection device at the user facility where the local loop ends and the user equipment begins

_____j. Refers to the tip and ring of the telephone plug

1. Branch exchange
2. Cable pair
3. Codec
4. Demarche
5. Ground start
6. Key system
7. Loop start
8. Off-hook
9. On-hook
10. Protector
11. Subscriber
12. Tip and ring

TEST

______k. The process of lifting the handset off the telephone, completing a DC path alerting the central office of an off-hook condition (loop start condition)

______l. A part of the PBX system which provides for centralized control of telephone functions such as intercom and paging

2. Match abbreviations related to telephone systems on the right with their correct meanings.

______a. Coder/Decoder

______b. Single Frequency

______c. Computerized Branch Exchange

______d. Private Automatic Branch Exchange

______e. Private Branch Exchange

______f. Bandwidth

______g. Telephone Company

______h. Stored Program Control

______i. Battery, Overvoltage protection, Ring voltage, Supervision, Coding, Hybrid, and Testing

______j. Federal Communication Commission

______k. Plain Old Telephone Service

______l. Ringer Equivalent Number

______m. Dial-tone Multifrequency

______n. Public Service Telephone Network

______o. Modulator/Demodulator

1. PBX
2. BORSCHT
3. PABX
4. CBX
5. SPC
6. MODEM
7. CODEC
8. DTMF
9. REN
10. SF
11. FCC
12. BW
13. Telco
14. POTS
15. PSTN

TEST

3. Match types of communication facilities on the right with their correct descriptions.

______a. An electronic circuit used to convert analog to digital or digital to analog signals

______b. The interconnection point within the local loop where the two wire subscriber lines and the multi-cable lines are connected

______c. A switching center where the local switch will transfer a call when lines directly between local switches are unavailable

______d. The sectional center tries to transmit back to a different primary center in order to complete the transmission

______e. The switching center where the transmission comes to when all other paths are being used as a final route

______f. The local switch where the subscriber equipment is interconnected to the appropriate path whether to another central office, to a tandem switch, or to a toll center

______g. The device used by the subscriber to transmit and receive signals, such as the telephone or computer terminal

______h. Transfers the transmission to a sectional center or regional center in order to complete the transmission

______i. A switching center that receives long distance transmissions from the central office and connects to another toll center when possible; if no circuits are available, then it connects to a primary center

1. Instrument
2. Cable termination box
3. Modem
4. Central office
5. Tandem switch
6. Toll center
7. Primary center
8. Sectional center
9. Regional center

4. Match telephone centers on the right with their correct classes.

______a. Class 1

______b. Class 2

______c. Class 3

______d. Class 4

______e. Class 5

1. Toll centers
2. Primary centers
3. Regional centers
4. Central office
5. Sectional centers

TEST

5. Distinguish between communication paths used in telephone systems by placing an "L" for local loop in the blank next to the correct description.

_____a. The interconnecting lines between the central offices, tandem switches, the various centers, and can be between the PBX and the central office

_____b. The interconnecting cable from the subscriber's facility to the central office

6. Complete the following statements concerning local loop functions by inserting the word(s) that best complete(s) each statement.

a. A battery voltage for ____________ phone systems, usually 48 VDC

b. An overvoltage protection device for voltage and lightning surges of up to ____________ volts

c. A ____________ voltage of 50-90 V at 70-100 hertz to indicate a ____________ is waiting

d. A supervision device which detects ____________ ____________ such as off-hook conditions and controlling calls in progress

e. Equipment which ____________ the voice signals into serial digital codes and then ____________ the signals at the receiver

f. A ____________ ____________ network which is used to convert two-wire to four-wire and four-wire to two-wire for long distance transmission

g. Testing of the circuit, provided through ____________ placed within the local loop circuitry

7. Match the types of branch exchanges on the right with their correct descriptions.

_____a. An exchange using stepper switches and crossbars

_____b. The switching in the exchange is controlled by digital computers

_____c. A manual device, where the operator must use jacks and patchcords to establish communications

_____d. The mechanical matrices were exchange with electronic matrices or switches and may use either analog or digital switching

_____e. Also a computer controlled exchange but uses stored programs for control

1. PBX
2. PABX
3. EPABX
4. CBX
5. SPC

TEST

8. Match functions of PBX key system on the right with their correct description.

_____a. If the line is busy the second incoming call will wait until the receiver is on-hook, then ring immediately

_____b. After a pre-determined number of rings, the call is transferred to another extension or sent back to the operator

_____c. One number is dialed but the call is put through to the next available extension of a group

_____d. If a particular number is called it rings at a location designated by the user.

_____e. An indication to the user that another call is waiting by transmitting a click or tone.

_____f. By dialing from two to four digits, frequently called numbers are automatically dialed

1. Call forwarding
2. Call waiting
3. Camp on
4. Call forward, no answer
5. Hunt group
6. Speed dialing

9. Distinguish among telephone dialing methods by placing a "P" for pulse dialing, an "E" for electronic pulse dialing, or a "D" for dual-tone multifrequency in the blanks preceding the correct descriptions.

_____a. Mechanical switch is replaced by an electronic circuit, a pulse dialer, that creates the loop current pulses

_____b. A rotary dial which when released, its rotation opens and closes a switch which creates loop current pulses according to the number dialed

_____c. A key pad in which low frequencies are applied horizontally and high frequencies are applied vertically, thus transmitting a low and high frequency for each key depressed

10. Complete the following statements concerning ringer equivalence requirements by inserting the word(s) that best complete(s) each statement.

a. The REN number for most phones will usually be _____________ _____________ _____________.

b. A maximum of _____________ REN ringing power is supplied by the central office.

c. If the _____________ ringing power is _____________ the telephone may not ring.

TEST

d. The suffix of ____________ on the REN number represents the old single party line of 20 ± 3 Hz and 30 ± 3Hz.

e. The suffix of ____________ on the REN number represents the new frequency of 15.3 Hz to 68 Hz.

11. Match telephone system characteristics on the right with their correct voltage and/or frequency requirements.

_____a. 60 lpm buzz

_____b. 48 VDC to 52 VDC

_____c. 0-4 KHz

_____d. 70-100 V at 16-60 Hz

_____e. 20 ± 3 Hz and 30 ± 3 Hz

_____f. 120 lpm buzz

_____g. 300 to 3000 Hz

_____h. 15.3 Hz to 68 Hz

1. Subscriber loop voltage
2. Ring voltage
3. A REN frequency
4. B REN frequency
5. Station busy signal
6. Equipment busy signal
7. Voice frequency
8. Allocated voice frequency BW

12. Distinguish among private line services used in telephone systems by placing a "D" for dedicated lines, a "P" for private lines, or an "L" for leased lines in the blanks preceding the correct descriptions.

_____a. The subscriber leases a loop to a dial switch of their choice which is constantly available and allows toll free calling

_____b. Lines leased by the subscriber on a 24 hour time period and are constantly available

_____c. Consist of voice communication lines for station to station use

TEST

13. Complete the following chart by writing the correct subscriber line color codes in the blanks.

Conductors					
4		6		6	
R*	T**	R	T	R	T
Red	b. ____	Red	Green	d. ____________	White/Blue Band
a. ____	Black	Yellow	Black	Orange	White/Orange Band
		Blue	c. ______	Green	White/Green Band
		Red	Green	Blue/White Band	White/Blue Band
		Yellow	Black	Orange/White Band	White/Orange Band
		Blue/White Band	White/Blue Band	Green/White Band	White/Green Band

*R = RING
**T = TIP

14. Complete the following statements concerning telephone number codes by inserting the word(s) that best complete(s) each statement.

(1-918-455-0202)

a. The ____________ digit number is the extension number in a particular zone.

b. The three digit prefix, 455, is the ____________ or central office in a specific community served.

c. The ____________ digit, one or zero indicates the call is no longer limited to a particular zone and transfers the call to a toll center.

d. The three digit prefix, 918, indicates a different zone than the one where the call originated and indicates what ____________ to contact.

15. Complete the following statements concerning local loop cable characteristics by inserting the word(s) or number(s) that best complete each statement.

(26H88)

a. The first group of numbers represent the ____________ ____________.

TEST

b. The letter indicates the length in feet.

1. H — ____________

2. D — ____________

3. B — ____________

c. The last group of numbers represents the inductance value.

1. ____

2. ____

3. ____

16. List transmission parameters for each of the following categories.

a. Bandwidth parameters

1. ____

2. ____

b. Interface parameters

1. ____

2. ____

3. ____

4. ____

c. Facility parameters

1. ____

2. ____

3. ____

4. ____

TEST

17. Complete the following statements concerning the types of line conditioning by inserting the word(s) that best complete(s) each statement.

    a. C type conditioning specifies the maximum limits for ____________ ____________ and ____________ ____________ ____________.

        1. C1 and C2 conditioning pertain to ____________ ____________ and ____________ circuits.

        2. C3 conditioning pertains to ____________ ____________ and ____________ ____________.

        3. C4 conditioning pertains to two point and multipoint circuits with a maximum of ____________ stations.

        4. C5 conditioning pertains to ____________ ____________ circuits only.

    b. D type conditioning sets the minimum requirements for ____________ ratio and deals with ____________ distortion.

        1. D-type conditioning is necessary with a faster data transmission rate beginning at approximately ____________ bps.

        2. D1 conditioning is used for ____________ circuits.

        3. D2 conditioning is used for ____________ circuits.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

18. Demonstrate the ability to:

    a. Analyze noise on a telephone system. (Job Sheet #1)

    b. Measure the ring signal of a telephone system. (Job Sheet #2)

TELEPHONE SYSTEMS
UNIT XV

ANSWERS TO TEST

1.	a.	3	d.	2	g.	7	j.	12
	b.	9	e.	1	h.	10	k.	8
	c.	11	f.	5	i.	4	l.	6

2.	a.	7	e.	1	i.	2	m.	8
	b.	10	f.	12	j.	11	n.	15
	c.	4	g.	13	k.	14	o.	6
	d.	3	h.	5	l.	9		

3.	a.	3	d.	8	g.	1
	b.	2	e.	9	h.	7
	c.	5	f.	4	i.	6

4.	a.	3
	b.	5
	c.	2
	d.	1
	e.	4

5. b

6.	a.	Subscriber
	b.	Codes, decodes, 1000
	c.	Ring, call
	d.	Line requests
	e.	Codes, decodes
	f.	Hybrid transformer
	g.	Relays

7.	a.	2
	b.	4
	c.	1
	d.	3
	e.	5

ANSWERS TO TEST

8. a. 3
b. 4
c. 5
d. 1
e. 2
f. 6

9. a. E
b. P
c. D

10. a. Less than one
b. Five
c. Maximum, exceeded
d. A
e. B

11. a. 5
b. 1
c. 8
d. 2
e. 3
f. 6
g. 7
h. 4
i. 9

12. a. L
b. P
c. D

13. a. Yellow
b. Green
c. White
d. Blue

14. a. Four
b. Zone
c. Single
d. Zone

ANSWERS TO TEST

15. a. Wire gauge
    b. 1. 6000 ft.
       2. 4500 ft.
       3. 3000 ft.

    c. 1. 44 mh
       2. 88 mh
       3. 135 mh

16. a. 1. Attenuation distortion
       2. Envelope delay distortion

    b. 1. Terminal impedance
       2. In-band and out-of-band signal power
       3. Test signal power
       4. Ground isolation

    c. 1. Noise measurement
       2. Frequency and phase distortion
       3. Amplitude distortion
       4. Nonlinear distortion

17. a. Attenuation distortion, envelope delay distortion

       1. Two-point, multipoint
       2. Access lines, trunk circuits
       3. Four
       4. Two-point

    b. Signal-to-noise, non-linear

       1. 4800
       2. Two-point
       3. Multipoint

18. Performance skills evaluated to the satisfaction of the instructor

DATA COMMUNICATIONS
UNIT XVI

UNIT OBJECTIVE

After completion of this unit, the student should be able to construct and analyze interfacing techniques, various networks, and error detection systems. Competencies will be demonstrated by completing the assignment sheet, job sheets, and the unit tests with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completion of this unit, the student should be able to:

1. Match terms related to data communications with their correct definitions.
2. Match abbreviations related to data communications with their correct definitions.
3. Match common data codes with their correct characteristics.
4. Select true statements concerning error detection methods.
5. Match data carriers with their descriptions.
6. List the four most common interfaces.
7. List the three basic types of networking.
8. Distinguish between types of protocols.
9. Match modems with their descriptions.
10. Distinguish between two methodologies of moving information.

OBJECTIVE SHEET

11. List four methods of testing data communications equipment.

12. Match types of data communications test equipment with their correct examples.

13. Determine parity bits for parity codes. (Assignment Sheet #1)

14. Demonstrate the ability to:

    a. Analyze and test a parity circuit. (Job Sheet #1)

    b. Construct a standard null-modem cable. (Job Sheet #2)

DATA COMMUNICATIONS
UNIT XVI

SUGGESTED ACTIVITIES

A. Obtain additional materials and/or invite resource people to supplement/reinforce information provided in this unit of instruction.

(NOTE: This activity should be completed prior to the teaching of this unit.)

B. Make transparencies from the transparency masters included with this unit.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and assignment sheets.

F. Discuss information and assignment sheets.

(NOTE: Use the transparencies to enhance the information as needed.)

G. Provide students with job sheets.

H. Discuss and demonstrate the procedures outlined in the job sheets.

I. Integrate the following activities throughout the teaching of this unit:

    1. Show examples of data communications systems such as computers, LAN's, etc.
    2. Invite a representative from industry to talk to class about data communication systems.
    3. Have students research common data codes and share their information with each other.
    4. Show examples of data communications test equipment to class and explain their uses.
    5. Have students visit an industry or university data communication center.
    6. Establish contact between terminals with a modem.
    7. Meet individually with students to evaluate their progress through this unit of instruction, and indicate to them possible areas for improvement.

J. Give test.

K. Evaluate test.

L. Reteach if necessary.

REFERENCES USED IN WRITING THIS UNIT

A. Sherman, Ken. *Data Communications, A User's Guide*. Second Edition. Reston, VA: Reston Publishing Company, 1985.

B. Seyer, Martin D. *The IBM PC/XT, Making the Right Connections*. Englewood Cliffs, NJ: Prentice Hall, Inc., 1985.

DATA COMMUNICATIONS
UNIT XVI

INFORMATION SHEET

I. **Terms and definitions**

A. Baud rate — The total number of transmissions per second; if various size bits are transmitted the duration of the smallest bit must be used

B. Bit — The smallest element of information or one binary digit, either a one or a zero

C. Bit rate — The total number of information bits transmitted per second

D. Breakout box — A test instrument placed between the DTE and the DCE to check or insert signals in the data path

E. Characters — A specific number of ones and zeros

F. Clock pulse — A pulse used to synchronize a digital circuit

G. Data — Information which can be produced or processed by a computer which is transferred from one point to another

H. Data communications — The technology of transferring data from one point to another between various distances

I. Network — The configuration of communication facilities that connects the user equipment to the TX/RX equipment

J. Sequential — The same information continues until changed, ie. upper case and lower case characters

II. **Abbreviations related to data communications**

A. ARQ — Automatic repeat request

B. ASCII — American National Standard Code for Information Interchange

C. AT&T — American Telephone and Telegraph Company

D. BCC — Block check character

E. BCD — Binary coded decimal

F. BCDIC — Binary coded decimal interchange code

G. BERT — Bit error rate tester

INFORMATION SHEET

H. BLERT — Block error rate tester

I. BPS — Bits per second

J. CERT — Character error rate tester

K. CRC — Cyclic redundancy check

L. CTS — Clear to send

M. DCD — Data carrier detect

N. DCE — Data communications equipment

O. DSU — Digital service unit

P. DTE — Data terminal equipment

Q. DTR — Data terminal ready

R. DTS — Digital termination system

S. EBCDIC — Extended binary coded decimal interchange code

T. EIA — Electronic Industries Association

U. FDX — Full-duplex

V. F/FDX — Full/full duplex

W. HDX — Half-duplex

X. IBM — International Business Machines

Y. LAN — Local area network

Z. LRC — Longitudinal redundancy check

AA. MCI — Microwave Communications Incorporated

BB. PAD — Packet assembly/disassembly facility

CC. PTTC — Paper tape transmission code

DD. RS232 — Recommended standard

EE. RTS — Request to send

FF. SPX — Simplex

INFORMATION SHEET

- GG. SRC — Spiral redundancy check
- HH. TELCO CO — Telephone company central office
- II. UART — Universal asynchronous receiver/transmitter
- JJ. VAN — Value-added network operators
- KK. VRC — Vertical redundancy check
- LL. TDM — Time-division multiplexing

III. Common data codes and their characteristics

- A. Morse code
  1. The first data communications code
  2. Used dots and dashes for communications
- B. Baudot code
  1. The first code using either a signal or no signal
  2. Requires a start and stop pulse
  3. The stop bit is one and one half bits long
  4. This code has no parity or error detection
  5. It is a sequential code
- C. BCD code
  1. Consists of only numeric characters
  2. Useful for calculations and storing information
- D. BCDIC code
  1. Consists of alpha and numeric characters
  2. Has no parity or error detection
  3. Contains a code for each character
- E. PTTC code
  1. Contains a parity error bit
  2. Code is sequential

INFORMATION SHEET

F. EBCDIC code — Contains an 8 bit code for each character (Transparency 1)

(NOTE: Even though the ability of the coding improved, an error detection system was needed. Thus IBM developed the BBC as an alternative.)

G. ASCII code (Transparency 2)

1. Contains a seven bit code plus a one bit parity

2. The most widely used data code in the nation

(NOTE: Both the EBDCIC and the ASCII codes have been modified by users, thus creating various control codes on the same systems.)

IV. **Error detection methods**

A. Echo checks — The information sent from one station to another is sent back to the original station and then compared for errors. Since other terminals cannot use the line while echo checks are performed, this is not a widely used detection method.

B. Parity checks — Where either a one or zero is added to the end of a character making an odd or even number of highs; the receiver can then check for this odd or even parity and determine if an error exists

1. VRC — One bit is added to each character to create an odd or an even parity

	#1	#2	#3
LSB	1	1	1
	0	0	0
	0	0	1
	1	0	0
	1	1	0
	0	1	1
MSB	0	0	1
Odd Parity	0	0	1
Even Parity	1	1	0

(NOTE: Since this method can only detect an odd number of errors, it is not widely used.)

INFORMATION SHEET

2. LRC — An additional seven bits are added to a group of characters to create an odd or even parity

	Characters						
	#1	#2	#3	#4	#5	Odd Parity	Even Parity
LSB	1	0	0	1	0	1	0
	0	1	0	1	1	0	1
	0	0	0	0	0	1	0
	1	0	1	0	1	0	1
	1	1	0	1	0	0	1
	1	1	0	1	1	1	0
MSB	0	1	1	0	1	0	1

(NOTE: If multiple errors were to occur they would possibly be in adjacent positions making error detection impossible; it is also not widely used.)

3. VRC/LRC — A combination of both methods for use with EBCDIC codes

	Characters					
	#1	#2	#3	#4	#5	Parity
LSB	1	1	1	1	1	0
	0	0	0	0	0	1
	0	0	0	1	0	0
	1	0	0	0	1	1
	1	1	0	0	1	0
	0	0	0	1	1	1
MSB	0	1	1	0	0	1
Parity	0	0	1	0	1	1

4. BCC — All characters of the block are added, then the least significant 16 bits are used for error detection.

(NOTE: Since EBDCIC uses eight bits for each character, BCC is the most widely used error detection method for this code.)

INFORMATION SHEET

5. SRC — The bits of each block of characters are calculated diagonally.

Characters

	#1	#2	#3	#4	#5	#6	#7	#8	#9	Parity
LSB	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	0
	0	0	1	0	0	1	0	0	0	0
	0	0	0	0	0	0	0	1	1	1
	0	0	0	0	0	0	1	0	0	0
	1	1	1	0	0	0	0	1	1	0
	0	0	0	1	0	1	0	1	0	1
MSB	1	0	0	1	1	1	1	0	1	0

(NOTE: The SRC method is not a great improvement on the LRC method.)

6. CRC — A mathematical polynomial is used. $X^{16} + X^{15} + X^2 + 1$ or 11000000000000101, which is the divisor, where the remainder on both the transmitter and receiver must compare.

(NOTE: The CRC error detection method is the most accurate and widely used method.)

V. Types of data carriers

A. Local carrier (common carrier) — The line connecting the user's equipment to the local telephone network (Transparency 3)

B. Long distance carrier (satellite carrier) — Communications connections locally and nationwide

C. Value-added network — Data carriers who provide an added service through the carriers

D. Resale carrier — A carrier provider who leases lines from other carriers

E. Radio carriers — Carriers who provide service through radio links such as cellular phones

F. Digital termination systems — Alternative between direct communications with satellite or telephone company

INFORMATION SHEET

VI. **Common interfaces** (Transparency 3)

(NOTE: The EIA, in conjunction with Bell systems, developed a standard interface, the RS232, for data communications equipment.

A. RS232

B. V.24

(NOTE: This interface is compatible with the RS232 and was established to interface with circuits of foreign countries.)

C. RS449

(NOTE: The RS449, which included the balanced RS422 and the unbalanced RS423 was to replace the RS232, but due to the new LAN the RS232 continued to be used.)

D. IEEE-488

(NOTE: This is the most accepted interface used to connect test equipment to data systems.)

VII. **Basic types of networking**

A. Packet switching — Where groups of data called packets are sent as a complete packet with charges only for that time and distance

B. LAN — Local Area Network

VIII. **Types of protocols**

A. Line discipline — Types of communications lines (Transparency 4)

1. SPX
2. HDX
3. FDX
4. F/FDX

B. Handshaking — Process to establish a communications line

1. Dial up — Routing through whatever lines are available
2. Dedicated lines — Privately leased lines for a specified time

INFORMATION SHEET

IX. **Modems**

A. Modulator — Device that converts digital to analog signals

B. Demodulator — Device that connects analog to digital signals

C. DSU — Device that converts digital signals into pulse transmitted signals

X. **Methodology of moving information**

A. Asynchronous — Transmission of characters at random, with a start and stop pulse

B. Synchronous — Transmission of characters at specific times, through clock pulses

XI. **Methods of testing data communications equipment**

A. Manual test — Equipment manually connected by technician

B. Switching test — Equipment previously connected through relays and switches to be activated by technician

C. Computerized test — Testing through use of a computer operated by a technician

D. Computer controlled test — Pre-programmed computers used without the use of a technician

XII. **Types of data communications test equipment**

A. Analog test equipment

1. Signal level meter
2. Signal/noise ratio meter
3. Signal generator
4. Line monitors

B. Digital test equipment

1. BERT
2. CERT
3. BLERT
4. Breakout box
5. Loop-back adapter

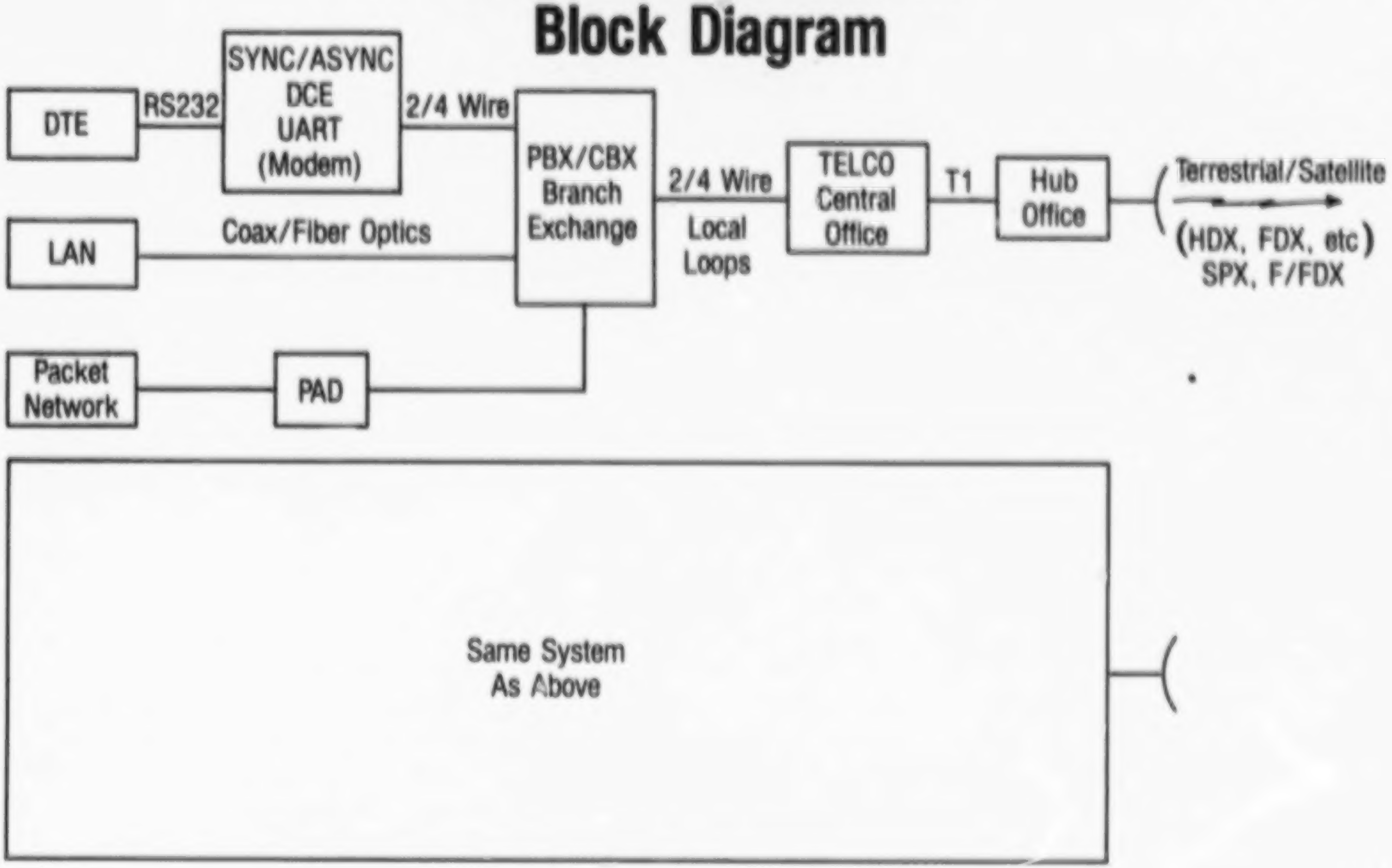
EBCDIC Code

Bits			4	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
			3	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
			2	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
			1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
8	7	6	5																
0	0	0	0	NUL	SOH	STX	ETX	PF	HT	LC	DEL			SMM	VT	FF	CR	SO	SI
0	0	0	1	DLE	DC_1	DC_2	DC_3	RES	NL	BS	IL	CAN	EM	CC		IFS	IGS	IRS	IUS
0	0	1	0	DS	SOS	FS		BYP	LF	EOB	PRE			SM			ENQ	ACK	BEL
0	0	1	1			SYN		PN	RS	UC	EOT					DC_4	NAK		SUB
0	1	0	0	SP										¢	.	>	(	+	|
0	1	0	1	&										!	$	*	)	;	
0	1	1	0	–	/										,	%	–	<	?
0	1	1	1											:	#	@	'	=	"
1	0	0	0		a	b	c	d	e	f	g	h	i						
1	0	0	1		j	k	l	m	n	o	p	q	r						
1	0	1	0			s	t	u	v	w	x	y	z						
1	0	1	1																
1	1	0	0		A	B	C	D	E	F	G	H	I						
1	1	0	1		J	K	L	M	N	O	P	Q	R						
1	1	1	0			S	T	U	V	W	X	Y	Z						
1	1	1	1	0	1	2	3	4	5	6	7	8	9						□

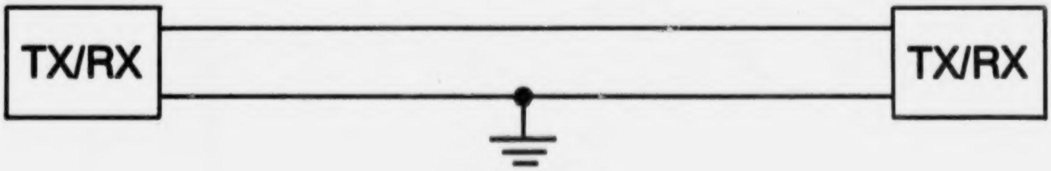
ASCII Code

	0000 0	0001 1	0010 2	0011 3	0100 4	0101 5	0110 6	0111 7	1000 8	1001 9	1010 A	1011 B	1100 C	1101 D	1110 E	1111 F
000 0	↑@ 0 NUL	↑A 1 SOH	↑B 2 STX	↑C 3 ETX	↑D 4 EOT	↑E 5 ENG	↑F 6 ACK	↑G 7 BEL	↑H 8 BS	↑I 9 HT	↑J 10 LF	↑K 11 VT	↑L 12 FF	↑M 13 CR	↑N 14 SO	↑O 15 SI
001 1	↑P 16 DLE	↑Q 17 DC1	↑R 18 DC2	↑S 19 DC3	↑T 20 DC4	↑U 21 NAK	↑V 22 SYN	↑W 23 ETB	↑X 24 CAN	↑Y 25 EM	↑Z 26 SUB	↑[27 ESC	↑\ 28 FS	↑] 29 GS	↑↑ 30 RS	↑← 31 VS
010 2	32 SP	33 !	34 "	35 #/£	36 $	37 %	38 &	39 '	40 (	41)	42 *	43 +	44 ,	45 –	46 .	47 /
011 3	48 0	49 1	50 2	51 3	52 4	53 5	54 6	55 7	56 8	57 9	58 :	59 ;	60 <	61 =	62 >	63 ?
100 4	64 @	65 A	66 B	67 C	68 D	69 E	70 F	71 G	72 H	73 I	74 J	75 K	76 L	77 M	78 N	79 O
101 5	80 P	81 Q	82 R	83 S	84 T	85 U	86 V	87 W	88 X	89 Y	90 Z	91 [	92 \	93]	94 ↑	95 ←
110 6	96	97 a	98 b	99 c	100 d	101 e	102 f	103 g	104 h	105 i	106 j	107 k	108 l	109 m	110 n	111 o
111 7	112 p	113 q	114 r	115 s	116 t	117 u	118 v	119 w	120 x	121 y	122 z	123 {	124 |	125 }	126 ~	127 DEL

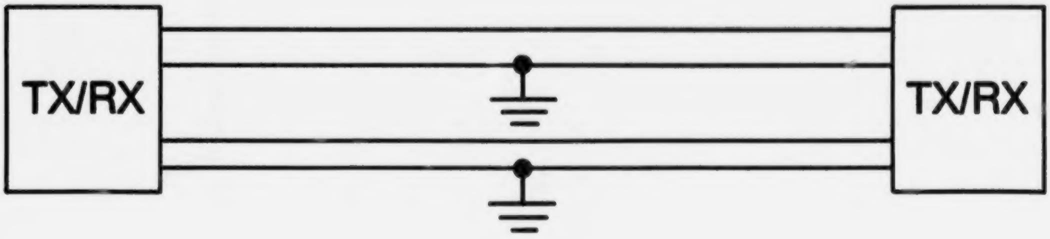
Data Communication Block Diagram


DTE
RS232
SYNC/ASYNC DCE UART (Modem)
2/4 Wire
LAN
Coax/Fiber Optics
Packet Network
PAD
PBX/CBX Branch Exchange
2/4 Wire
Local Loops
TELCO Central Office
T1
Hub Office
Terrestrial/Satellite
(HDX, FDX, etc)
SPX, F/FDX
Same System As Above

Communications Lines



SPX/HDX



FDX

DATA COMMUNICATIONS
UNIT XVI

ASSIGNMENT SHEET #1 — DETERMINE PARITY BITS FOR PARITY CODES

NAME ____________________ SCORE ____________________

In order to analyze data circuits a technician should be familiar with odd and even parity.

Directions: For the charts below, fill in the parity bits for the type of parity indicated.

A. VRC

	#1	#2	#3	#4
LSB	1	1	1	1
	0	0	0	0
	0	0	1	0
	0	0	0	0
	1	0	1	0
	0	0	0	0
MSB	0	1	0	1
Odd Parity	____	____	____	____

B. LRC

						Even Parity
LSB	0	1	1	1	0	____
	1	0	0	0	1	____
	0	0	0	1	0	____
	1	1	1	0	1	____
	0	1	1	0	0	____
	0	0	1	1	0	____
MSB	0	0	0	1	1	____

ASSIGNMENT SHEET #1

C. SRC

										Odd Parity
LSB	0	1	1	1	1	1	1	1	0	____
	1	1	1	1	1	1	1	1	1	____
	0	1	0	0	0	0	0	1	0	____
	0	0	0	0	0	0	1	0	1	____
	1	0	1	0	0	0	1	0	1	____
	1	0	0	1	0	1	0	0	1	____
	0	1	0	0	1	0	0	1	0	____
MSB	1	0	1	1	0	1	1	1	1	____

DATA COMMUNICATIONS
UNIT XVI

ANSWERS TO ASSIGNMENT SHEET #1

A.

#1	#2	#3	#4
1	1	0	1

B.

LSB	1
	0
	1
	0
	0
	0
MSB	0

C.

LSB	0
	0
	1
	1
	0
	0
	0
MSB	0

DATA COMMUNICATIONS
UNIT XVI

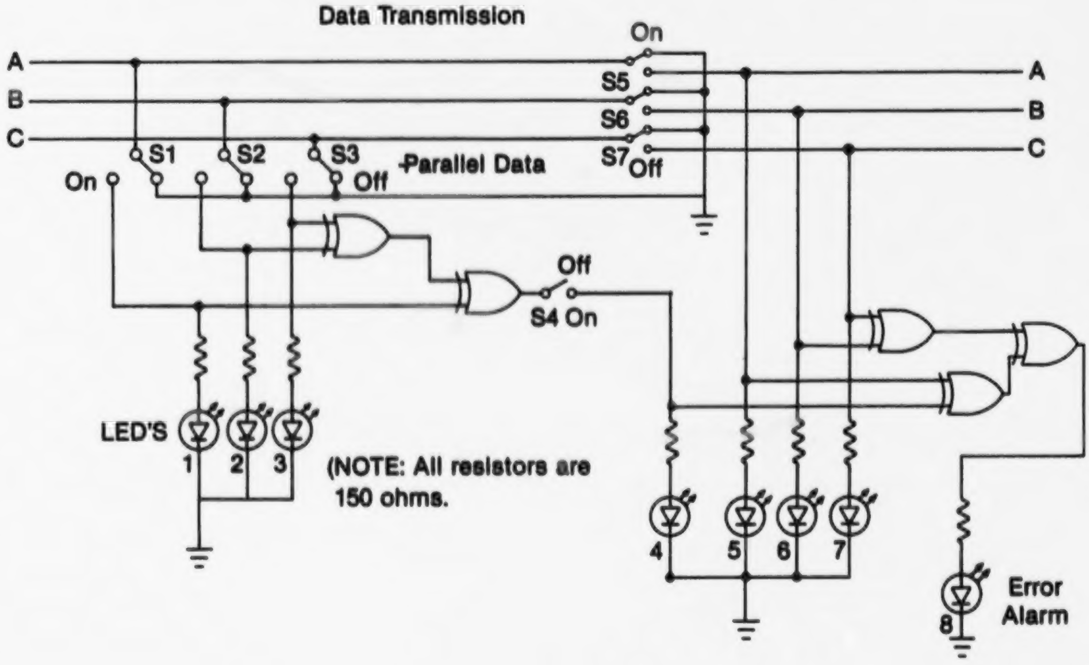
JOB SHEET #1 — ANALYZE AND TEST A PARITY CIRCUIT

A. Equipment and materials needed

1. Switches: 1 each SPST, 6 each SPDT
2. LED's: 8 each
3. IC, XOR: 2 each 7486
4. Resistors: 8 each, 150 ohm
5. DC power supply
6. Proto board
7. Circuit wire
8. Data manual

B. Procedure

1. Study the circuit below.


Data Transmission
A
B
C
On
S5
S6
S7
Off
A
B
C
S1
S2
S3
On
Off
Parallel Data
Off
S4 On
LED'S
1
2
3
4
5
6
7
8
Error
Alarm

(NOTE: All resistors are 150 ohms.

JOB SHEET #1

2. Using the preceding circuit, fill in the blanks in the chart below indicating a "1" if the LED is on, or an "0" if the LED is off. Also indicate if there should be an error.

Inputs			Switch Pos							LED								Error	
A	B	C	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	Yes	No
1	1	1	ON	ON	ON	ON	ON	ON	ON										
1	1	1	OFF	ON	ON	ON	ON	ON	ON										
1	1	1	ON	ON	ON	OFF	ON	ON	ON										
1	0	1	ON	ON	ON	ON	ON	ON	ON										
1	0	1	ON	ON	ON	ON	OFF	ON	ON										
0	1	1	ON	ON	ON	ON													

3. Construct the circuit in step 1 above.

4. Turn on the power supply and set the output voltage for 5 VDC.

5. Connect the inputs of the circuit, inputs A, B, and C, as indicated in the chart below and note in the spaces provided, the LED indications and if an error is indicated.

Inputs			Switch Pos							LED								Error	
A	B	C	1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	Yes	No
1	1	1	ON	ON	ON	ON	ON	ON	ON										
1	1	1	OFF	ON	ON	ON	ON	ON	ON										
1	1	1	ON	ON	ON	OFF	ON	ON	ON										
1	0	1	ON	ON	ON	ON	ON	ON	ON										
1	0	1	ON	ON	ON	ON	OFF	ON	ON										
0	1	1	ON	ON	ON	ON													

6. Compare the results in step 2 and step 5. If any differences are indicated, list below and complete step 7.

____

____

JOB SHEET #1

7. Determine why there is a difference and note your findings below.

    ____

    ____

    ____

8. Show your results to the instructor.

9. Return equipment and materials to their proper storage location.

DATA COMMUNICATIONS
UNIT XVI

JOB SHEET #2 — CONSTRUCT A STANDARD NULL-MODEM CABLE

A. Equipment and materials needed

1. Cable connector plugs: 2 each (DB25P or DB25P)
2. Connecting cable
3. Tools

B. Procedure

1. Locate the appropriate plugs and cable for the specific null-modem cable.

   (NOTE: When equipment must be connected to peripheral equipment and a modem is not used, a null-modem cable provides this connection.)

2. First pin one on each plug should be connected.

   (NOTE: Pin one is the protective ground connecting both pieces of equipment.)

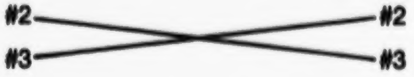
   #1 ———————— #1

3. Next connect pin seven of each plug.

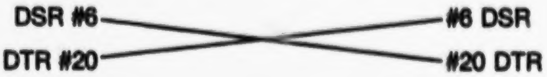
   (NOTE: Pin seven is the signal ground for the equipment used.)

   #7 ———————— #7

4. Connect pin two (transmitted data) of plug #1 to pin three (received data) of plug #2. Then connect pin two of plug #2 to pin three of plug #1.



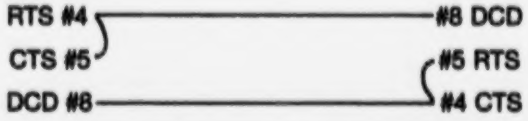
5. Connect pin twenty of plug #1 to pin six of plug #2. Then connect pin twenty of plug #2 to pin six of plug #1.



(NOTE: The DTR signal is provided to indicate the power is on. The DSR signal indicates that a line has been established.)

JOB SHEET #2

6. Now connect pin four to pin five of the DTE and connect pin four of the DTE to pin eight of the peripheral plug.



(NOTE: When the DTE sends a RTS signal it must receive a CTS signal indicating transmission is possible. At this time the peripheral equipment will receive a RTS at the DCD input.)

7. When completed, show the cable to the instructor.

8. If the appropriate equipment is available, test the plug for proper operation.

9. Return equipment and materials to their proper storage location.

(NOTE: The above connection is for an asynchronous serial interface. If a synchronous interface or an interface between different types of equipment or peripherals is needed the technician must familiarize himself/herself with that specific equipment.)

DATA COMMUNICATIONS
UNIT XVI

JOB SHEET #1 PRACTICAL TEST — ANALYZE AND TEST A PARITY CIRCUIT

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Correctly analyzed the parity circuit.	______	______
3. Correctly constructed the circuit.	______	______
4. Obtained proper output (parity) indications.	______	______
5. Properly utilized data manuals.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______
8. Used proper tools correctly.	______	______
9. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #1 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Circuit construction	Correct			Incorrect
	4	3	2	1
Parity readouts	Properly obtained			Improperly obtained

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

DATA COMMUNICATIONS
UNIT XVI

JOB SHEET #2 PRACTICAL TEST — CONSTRUCT A STANDARD NULL-MODEM CABLE

STUDENT'S NAME ______________________________ DATE ____________

EVALUATOR'S NAME ______________________________ ATTEMPT NO. ______

Instructions: When you are ready to perform this task, ask your instructor to observe the procedure and complete this form. All items listed under "Process Evaluation" must receive a "Yes" for you to receive an overall performance evaluation.

PROCESS EVALUATION

(EVALUATOR NOTE: Place a check mark in the "Yes" or "No" blanks to designate whether or not the student has satisfactorily achieved each step in this procedure. If the student is unable to achieve this competency, have the student review the materials and try again.)

The student:	YES	NO
1. Checked out proper tools and materials.	______	______
2. Obtained correct cable and connectors.	______	______
3. Fabricated null-modem cable.	______	______
4. Properly tested cable.	______	______
5. Properly soldered connectors.	______	______
6. Checked in/put away tools and materials.	______	______
7. Cleaned the work area.	______	______
8. Used proper tools correctly.	______	______
9. Performed steps in a timely manner. (___hrs. ___min. ___sec.)	______	______
10. Practiced safety rules throughout procedure.	______	______
11. Provided satisfactory responses to questions asked.	______	______

EVALUATOR'S COMMENTS: ____

____

JOB SHEET #2 PRACTICAL TEST

PRODUCT EVALUATION

(EVALUATOR NOTE: Rate the student on the following criteria by circling the appropriate numbers. Each item must be rated at least a "3" for mastery to be demonstrated. (See performance evaluation key below.) If the student is unable to demonstrate mastery, student materials should be reviewed and another product must be submitted for evaluation.)

Criteria:

	4	3	2	1
Connectors	Properly soldered			Improperly soldered
	4	3	2	1
Cable	Works correctly			Works incorrectly

EVALUATOR'S COMMENTS: ____

____

PERFORMANCE EVALUATION KEY

4 — Skilled — Can perform job with no additional training.
3 — Moderately skilled — Has performed job during training program; limited additional training may be required.
2 — Limited skill — Has performed job during training program; additional training is required to develop skill.
1 — Unskilled — Is familiar with process, but is unable to perform job.

(EVALUATOR NOTE: If an average score is needed to coincide with a competency profile, total the designated points in "Product Evaluation" and divide by the total number of criteria.)

DATA COMMUNICATIONS
UNIT XVI

TEST

NAME ____________________ SCORE ____________________

1. Match terms related to data communications on the right with their correct definitions.

_____a. The total number of transmissions per second; if various size bits are transmitted the duration of the smallest bit must be used.

_____b. The same information continues until changed, ie: upper case and lower case characters

_____c. A specific number of ones and zeros creating a set

_____d. The technology of transferring data from one point to another between various distances

_____e. The smallest element of information or one binary digit, either a one or a zero

_____f. A pulse used to synchronize a digital circuit

_____g. Information which can be produced or processed by a computer which is transferred from one point to another

_____h. The total number of information bits transmitted per second

_____i. The configuration of communication facilities that connects the user equipment to the TX/RX equipment

_____j. A test instrument placed between the DTE and the DCE to check or insert signals in the data path

1. Baud rate
2. Bit
3. Bit rate
4. Breakout box
5. Characters
6. Clock pulse
7. Data
8. Data communications
9. Networks
10. Sequential

TEST

2. Match abbreviations related to data communications on the right with their correct definitions.

______a. Binary coded decimal

______b. Paper tape transmission code

______c. Block check character

______d. International Business Machines

______e. Longitudinal redundancy check

______f. Cyclic redundancy check

______g. Microwave Communications Incorporated

______h. Digital termination system

______i. Bits per second

______j. Local area network

______k. Simplex

______l. Half-duplex

______m. Digital service unit

______n. Character error rate tester

______o. Universal asynchronous receiver/transmitter

______p. Packet assembly/disassembly facility

______q. Telephone Company Central Office

______r. Data carrier detect

______s. Clear to send

______t. Binary coded decimal interchange code

______u. Extended binary coded decimal interchange code

______v. American National Standard Code for Information Interchange

1. ARQ
2. ASCII
3. AT&T
4. BBC
5. BCD
6. BCDIC
7. BERT
8. BLERT
9. BPS
10. CERT
11. CRC
12. CTS
13. DCD
14. DCE
15. DSU
16. DTE
17. DTR
18. DTS
19. EIA
20. EBCDIC
21. FDX
22. F/FDX
23. HDX

TEST

______w. Vertical redundancy check

______x. Spiral redundancy check

______y. American Telephone and Telegraph Company

______z. Value-added network apparatus

______aa. Electronic Industries Association

______bb. Recommended standard

______cc. Automatic repeat request

______dd. Full-duplex

______ee. Full/full duplex

______ff. Bit error rate tester

______gg. Black error rate tester

______hh. Data terminal equipment

______ii. Data communications equipment

______jj. Data terminal ready

______kk. Request to send

______ll. Time-division multiplexing

24. IBM
25. LAN
26. LRC
27. MCI
28. PAD
29. PTTC
30. RS232
31. TDM
32. SPX
33. SRC
34. TELCO CO
35. UART
36. VAN
37. VRC
38. RTS

3. Match common data codes on the right with their correct characteristics. Some characteristics may describe more than one code.

______a. The first data communications code

______b. The first code using either a signal or no signal

______c. Code is sequential

______d. The most widely used data code in the nation

______e. Has no parity or error detection

______f. Consists of only numeric characters

1. PTTC code
2. BCD code
3. ASCII code
4. Morse code
5. EBCDIC code
6. Baudot code
7. BCDIC code

TEST

_____g. Used dots and dashes for communications

_____h. Contains a seven bit code plus a one bit parity

_____i. The stop bit is one and one half bits long

_____j. Contains an eight bit code for each character

_____k. Contains a parity error bit

_____l. Requires a start and stop pulse

_____m. Useful for calculations and storing information

_____n. Contains a code for each character

_____o. Consists of alpha and numeric characters

4. Select true statements concerning error detection methods by placing an "X" in the blanks preceding the true statements.

_____a. Since other terminals cannot use the line while echo checks are performed, this is not a widely used detection method.

_____b. Parity checks are where either a one or zero is added to the end of a character making an odd or even number of highs; the receiver can then check for this odd or even parity and determine if an error exists.

_____c. With the LRC one bit is added to each character to create an odd or an even parity.

_____d. With the VRC an additional five bits are added to a group of characters to create an odd or even parity

_____e. VRC/LRC represents a combination of both methods for use with EBCDIC codes.

_____f. When using the BCC method all characters of the block are added, then the least significant 16 bits are used for error detection.

_____g. For the SRC method a mathematical polynomial is used, which is the divisor, where the remainder on both the transmitter and receiver must compare.

TEST

5. Match types of data carriers on the right with their descriptions.

   ______a. Carriers who provide service through radio links such as cellular phones

   ______b. Data carriers who provide an added service through the carriers

   ______c. The line connecting the user's equipment to the local telephone network

   ______d. Alternative between direct communications with satellite or telephone company

   ______e. A carrier provider who leases lines from other carriers

   ______f. Communications connections locally and nationwide

   1. Local carrier
   2. Long distance carrier
   3. Value-added network
   4. Resale carrier
   5. Radio carriers
   6. Digital termination system

6. List the four most common interfaces.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

7. List the two basic types of networking.

   a. ______________________________

   b. ______________________________

8. Distinguish between types of protocols by placing an "H" for handshaking next to the correct examples.

   ______a.
   1) SPX
   2) HDX
   3) FDX
   4) F/FDX

   ______b.
   1) Dial up
   2) Dedicated lines

TEST

9. Match the modems on the right with their descriptions.

_____a. Device that converts digital to analog signals

_____b. Device that converts digital signals into pulse transmitted signals

_____c. Device that converts analog to digital

1. Modulator
2. Demodulator
3. DSU

10. Distinguish between two methodologies of moving information by placing an "A" next to the description of asynchronous.

_____a. Transmission of characters at specific times, through clock pulses

_____b. Transmission of characters at random, with a start and stop pulse

11. List four methods of testing data communications equipment.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

12. Match types of data communications test equipment on the right with their correct examples.

_____a. Line monitors

_____b. Signal generator

_____c. BERT

_____d. Loop-back adaptor

_____e. BLERT

_____f. Signal level meter

_____g. CERT

_____h. Breakout box

_____i. Signal/noise ratio meter

1. Analog
2. Digital

TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

13. Determine parity bits for parity codes. (Assignment Sheet #1)

14. Demonstrate the ability to:

    a. Analyze and test a parity circuit. (Job Sheet #1)

    b. Construct a standard null-modem cable. (Job Sheet #2)

DATA COMMUNICATIONS
UNIT XVI

ANSWERS TO TEST

1.	a.	1	f.	6
	b.	10	g.	7
	c.	5	h.	3
	d.	8	i.	9
	e.	2	j.	4

2.	a.	5	n.	10	aa.	19
	b.	29	o.	35	bb.	30
	c.	4	p.	28	cc.	1
	d.	24	q.	34	dd.	21
	e.	26	r.	13	ee.	22
	f.	11	s.	12	ff.	7
	g.	27	t.	6	gg.	8
	h.	18	u.	20	hh.	16
	i.	9	v.	2	ii.	14
	j.	25	w.	37	jj.	17
	k.	32	x.	33	kk.	38
	l.	23	y.	3	ll.	31
	m.	15	z.	36		

3.	a.	4	f.	2	k.	1
	b.	6	g.	4	l.	6
	c.	6,1	h.	3	m.	2
	d.	3	i.	6	n.	7
	e.	6,7	j.	5	o.	7

4. a, b, e, f

5.	a.	5
	b.	3
	c.	1
	d.	6
	e.	4
	f.	2

6.	a.	RS232
	b.	V.24
	c.	RS449
	d.	IEEE-488

ANSWERS TO TEST

7. a. Packet switching
   b. LAN

8. b

9. a. 1
   b. 3
   c. 2

10. b

11. a. Manual tests
    b. Switching tests
    c. Computerized
    d. Computer controlled

12. a. 1
    b. 1
    c. 2
    d. 2
    e. 2
    f. 1
    g. 2
    h. 2
    i. 1

13. Evaluated to the satisfaction of the instructor

14. Performance skills evaluated to the satisfaction of the instructor